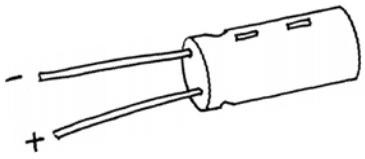
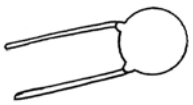
RADIOSHACK ELECTRONICS LEARNING LAB

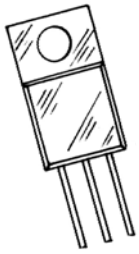
WORKBOOK 1. BASIC ELECTRONICS,

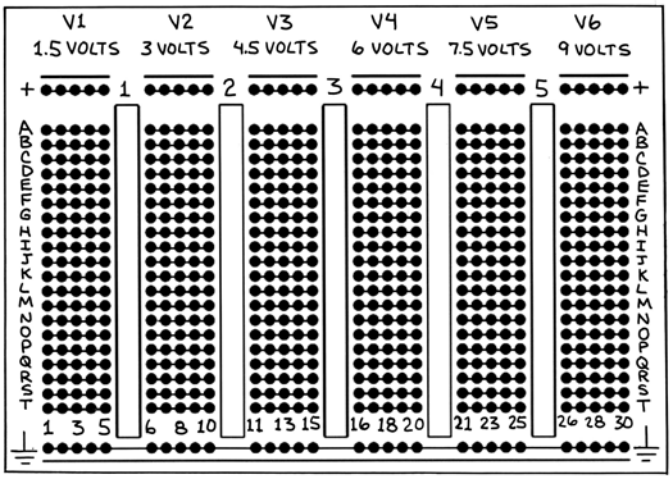
TRANSISTORS AND INTEGRATED CIRCUITS

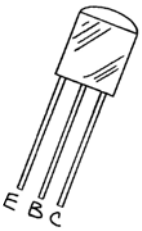
BY FORREST M. MIMS III

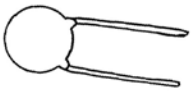


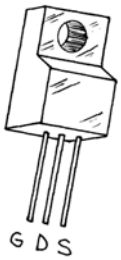


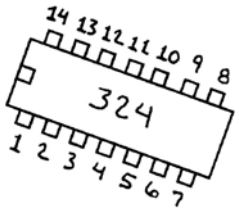


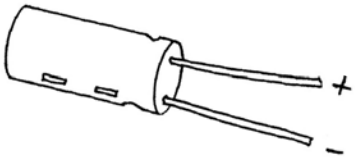


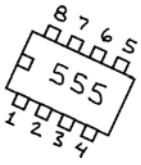












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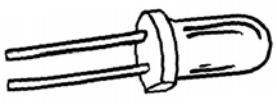
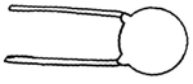
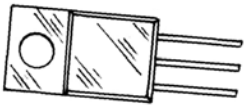






CONTENTS

A NOTE FROM THE AUTHOR...

CONGRATULATIONS! YOU ARE ABOUT TO ENTER THE EXCITING WORLD OF SOLID-STATE ELECTRONICS. THE PROJECTS IN THIS MANUAL WILL TEACH YOU MANY OF THE BASIC PRINCIPLES OF ELECTRONICS USING CIRCUITS THAT ARE AS MUCH FUN AS THEY ARE EDUCATIONAL. BY THE TIME YOU BUILD ALL THE CIRCUITS IN THIS WORKBOOK, YOU WILL BE WELL ON THE WAY TO DESIGNING YOUR OWN ELECTRONIC CIRCUITS. AND YOU'LL BE WELL EQUIPPED TO BEGIN THE DIGITAL LOGIC WORKBOOK THAT IS ALSO PROVIDED WITH YOUR ELECTRONICS LEARNING LAB.

FORREST M. MIMS III

HOW TO CARE FOR YOUR ELECTRONICS LEARNING LAB

1. ALWAYS PUSH THE POWER SWITCH TO THE OFF POSITION (DOWN) BEFORE BUILDING OR MODIFYING A CIRCUIT AND WHEN YOU ARE NOT USING THE LEARNING LAB.

2. IF A CIRCUIT FAILS TO WORK PROPERLY WHEN THE POWER SWITCH IS PUSHED ON (UP), PUSH THE SWITCH OFF (DOWN) UNTIL YOU FIND AND CORRECT THE PROBLEM (SEE PAGE 18).

3. OVERHEATED ELECTRONIC COMPONENTS OFTEN EMIT A DISTINCTIVE ODOR. VERY IMPORTANT: IF YOU NOTICE AN ODOR AFTER SWITCHING THE POWER SWITCH ON, PUSH THE SWITCH OFF AND CHECK YOUR WIRING FOR POSSIBLE ERRORS.

4. NEVER MAKE A DIRECT CONNECTION BETWEEN ANY OF POWER SUPPLY POINTS (V1 THROUGH V6) AND GROUND.

5. THE CONSOLE LEDS, SEVEN-SEGMENT READOUT AND POTENTIOMETERS HAVE BUILT-IN SERIES RESISTORS TO LIMIT (REDUCE) CURRENT. WHEN USING THE LOOSE LEDS, BE SURE TO INCLUDE A SERIES RESISTOR OF A FEW HUNDRED OHMS OR MORE. SEE PAGE 48 FOR DETAILS.

6. STORE THE LOOSE PARTS PROVIDED WITH YOUR LEARNING LAB IN SMALL BOXES OR PLASTIC BAGS. THE INTEGRATED CIRCUITS AND THE POWER FET TRANSISTOR SHOULD NOT BE STORED IN A PLASTIC BAG OR CONTAINER AS THEY CAN BE DAMAGED BY STATIC ELECTRICITY. WHILE BUILDING CIRUITS, YOU CAN TEMPORARILY STORE PARTS YOU ARE USING BY INSERTING THEM INTO AN UNUSED PORTION OF THE BREADBOARD. JUST BE SURE THAT NO COMPONENTS OR WIRES FROM YOUR CIRCUITS ARE PLUGGED INTO ANY OF THE ADJACENT HOLES.

7. HANDLING PRECAUTIONS FOR CMOS INTEGRATED CIRCUITS: THE DIGITAL LOGIC CHIPS PROVIDED WITH YOUR LEARNING LAB ARE OF THE CMOS FAMILY. THE DIGITAL LOGIC PROJECTS MANUAL PROVIDES IMPORTANT INFORMATION ABOUT THE HANDLING AND USE OF THESE CHIPS. BE SURE TO REVIEW THIS INFORMATION TO AVOID DAMAGING THE CMOS CHIPS.

8. PANEL METER PRECAUTIONS: THE ANALOG PANEL METER IS VERY DELICATE. NEVER CONNECT IT DIRECTLY ACROSS ANY OF THE POWER SUPPLY OUTLETS ON YOUR BREADBOARD. DOING SO MAY RUIN THE MOVING COIL INSIDE THE METER OR PEG THE NEEDLE SO HARD THAT IT WILL BE BENT. FOR THIS REASON YOU SHOULD NEVER APPLY POWER TO A CIRCUIT THAT USES THE METER UNTIL YOU HAVE CAREFULLY CHECKED YOUR WIRING AND CORRECTED ANY ERRORS.

BATTERIES

YOUR LEARNING LAB REQUIRES SIX AA CELLS. REMOVE THE BATTERY COVER ON THE BOTTOM OF THE CONSOLE AND INSERT THE BATTERIES IN THE PROPER DIRECTION AS INDICATED.

THE TOP ROW OF CONTACT HOLES (V1 THROUGH V6) ON THE BREADBOARD PROVIDES SIX DIFFERENT VOLTAGES FROM THE BATTERIES. THE VOLTAGES ARE 1.5 (V1), 3.0 (V2), 4.5 (V3), 6 (V4), 7.5 (V5) AND 9 (V6) VOLTS. THESE VOLTAGES ARE IMPORTANT TO SOME OF THE PROJECTS. SO BE SURE THAT THE BATTERIES ARE REASONABLY FRESH WHEN YOU ARE BUILDING PROJECTS WITH YOUR LEARNING LAB.

THE BATTERIES WILL LAST UP TO SEVERAL MONTHS, IF YOU REMEMBER TO SWITCH THE POWER SWITCH ON YOUR LEARNING LAB OFF WHEN IT IS NOT BEING USED.

BE SURE TO REMOVE THE BATTERIES IF YOU PLAN TO STORE THE CONSOLE FOR AN EXTENDED PERIOD OF TIME.

FREQUENTLY ASKED QUESTIONS

1. "DO I HAVE TO BUILD THE CIRCUITS IN THE ORDER THEY ARE GIVEN?"

NO. BUT IF YOU ARE NEW TO ELECTRONICS, OR IF THIS IS YOUR FIRST LAB KIT, IT'S BEST TO GO THROUGH THIS WORKBOOK FIRST. THIS WILL HELP YOU LEARN WHAT YOU NEED TO KNOW TO HAVE THE MOST FUN WITH, AND TO LEARN THE MOST FROM, YOUR LEARNING LAB.

2. "THERE ARE MANY WAYS TO BUILD CIRCUITS. DO I HAVE TO FOLLOW THE CHECK LISTS?"

IF YOU ARE NEW TO ELECTRONICS, YES. WITH A LITTLE EXPERIENCE, YOU WILL SOON BE BUILDING THE CIRCUITS STRAIGHT FROM THE CIRCUIT DIAGRAMS.

3. "WHAT DO I DO WHEN A CIRCUIT DOES NOT WORK?"

IF YOU FOLLOW THE INSTRUCTIONS AND USE REASONABLE CARE, CIRCUITS SHOULD WORK THE FIRST TIME YOU PUSH THE POWER SWITCH ON. WHEN A CIRCUIT DOES NOT WORK, PUSH THE POWER SWITCH OFF AND TURN TO PAGE 18 FOR SOME TROUBLESHOOTING TIPS.

4. "IS IT OK TO MODIFY OR CHANGE THE CIRCUITS IN MY LEARNING LAB MANUALS?"

YES. EVEN AFTER YOU BUILD A CIRCUIT, THERE WILL ALWAYS BE PLENTY OF LEFT OVER PARTS FOR MAKING CHANGES. BUT YOU MUST FOLLOW BASIC ELECTRONIC DESIGN GUIDELINES BEFORE MAKING SUCH CHANGES. OTHERWISE YOU WILL PROBABLY DAMAGE SENSITIVE PARTS LIKE ICS AND TRANSISTORS. SO IF YOU ARE NEW TO ELECTRONICS, WAIT UNTIL YOU'VE BUILT MOST OR EVEN ALL THE PROJECTS IN THE TWO MANUALS SUPPLIED WITH YOUR LEARNING LAB BEFORE MODIFYING YOUR CIRCUITS. BY THEN YOU MIGHT EVEN BE ABLE TO DESIGN YOUR OWN CIRCUITS.

5. "CAN I USE THE CIRCUITS IN MY LEARNING LAB IN PROJECTS FOR SCHOOL OR AT WORK?"

GENERALLY, YES. BUT SINCE THE AUTHOR AND RADIOSHACK HAVE NO CONTROL OVER WHAT YOU DO WITH YOUR LEARNING LAB, WE ARE NOT RESPONSIBLE FOR ANY ADVERSE CONSEQUENCES. FOR EXAMPLE, YOU SHOULD NEVER USE YOUR LEARNING LAB OR ITS CIRCUITS FOR MEDICAL APPLICATIONS, SAFETY DEVICES, TRAFFIC CONTROLLERS OR ANY OTHER USE THAT MIGHT SOMEHOW RESULT IN DAMAGE TO PROPERTY OR INJURY TO YOU OR OTHERS.

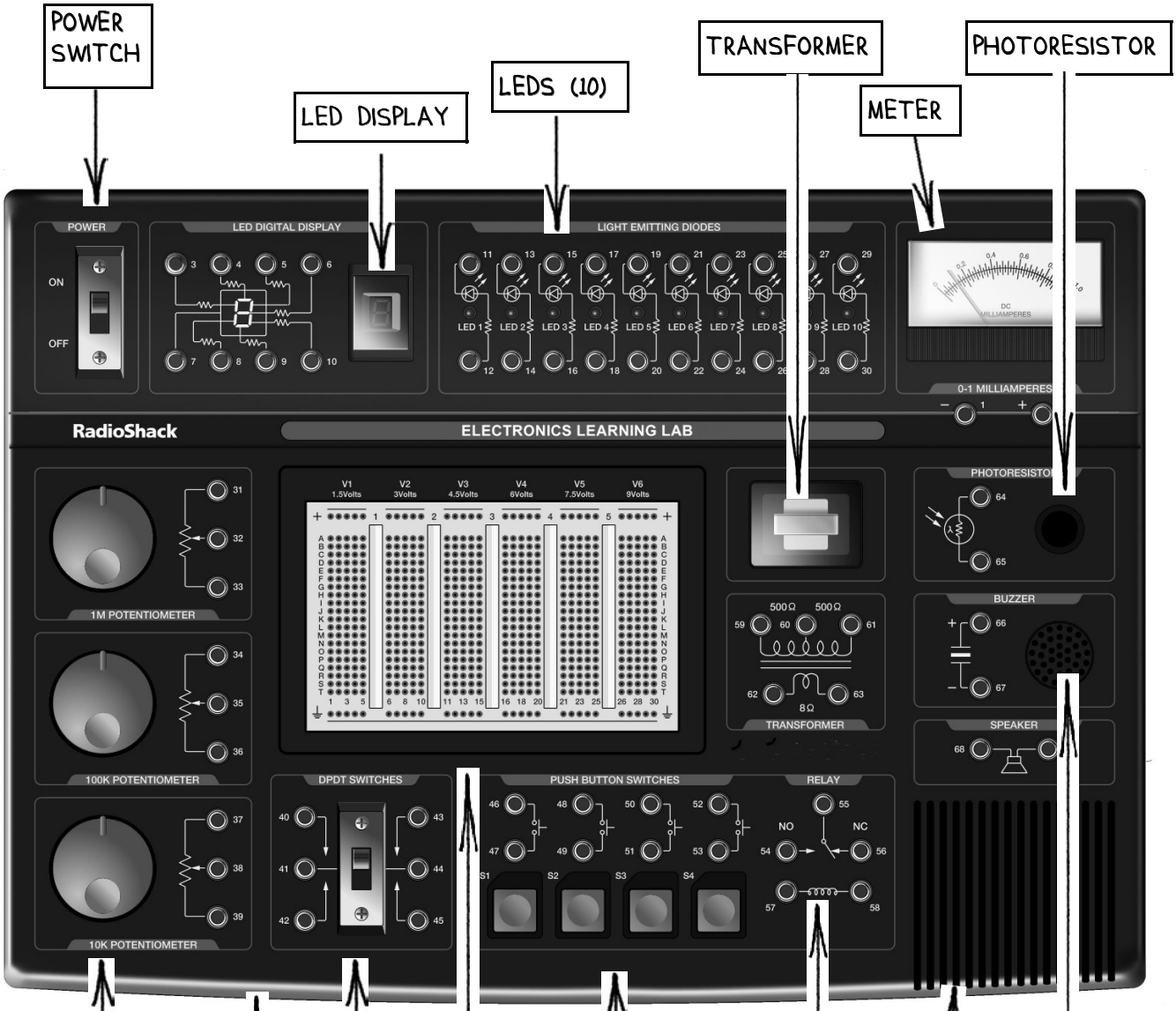
THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

YOU WILL LEARN MUCH AND YOU WILL HAVE LOTS OF FUN AS YOU EXPLORE THE EXCITING AND ENTERTAINING WORLD OF SOLID STATE ELECTRONICS WITH YOUR ELECTRONICS LEARNING LAB. YOU MIGHT EVEN THINK ABOUT FORMAL ELECTRONICS TRAINING SOME DAY. IF SO, YOU WILL WANT TO KNOW ABOUT THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE), THE WORLD'S LARGEST PROFESSIONAL SOCIETY FOR ELECTRICAL ENGINEERS. YOU CAN FIND IEEE MAGAZINES AND TECHNICAL JOURNALS AT COLLEGE LIBRARIES. YOU CAN LEARN MORE ABOUT THE IEEE BY VISITING ITS WEB SITE (WWW.IEEE.ORG).

MANY IEEE MEMBERS FIRST LEARNED ABOUT ELECTRONICS BY BUILDING CIRCUITS MUCH LIKE THOSE IN YOUR LEARNING LAB. THEY KNOW THAT THEIR WORK INFLUENCES THE LIVES, HEALTH AND SAFETY OF PEOPLE THROUGHOUT THE WORLD. THEREFORE, IEEE MEMBERS HAVE COMMITTED THEMSELVES TO PRACTICING THE HIGHEST ETHICAL AND PROFESSIONAL CONDUCT. MEMBERS AGREE TO ABIDE BY A CODE OF ETHICS THAT RECOGNIZES THE IMPORTANCE OF HONESTY, INTEGRITY, FAIRNESS AND SAFETY. THESE SAME PRINCIPLES CAN SERVE AS YOUR ETHICAL COMPASS AS YOU EXPLORE THE AMAZING WORLD OF ELECTRONICS.

THE CONSOLE ELECTRONIC PARTS

MOST OF THE ELECTRONIC PARTS INSTALLED ON THE CONSOLE ARE NOT EASILY INSTALLED ON A SOLDERLESS BREADBOARD. INSTALLING THEM ON THE CONSOLE AND CONNECTING THEIR LEADS TO CONNECTION SPRINGS MAKES THEM VERY EASY TO USE. COMPARE YOUR LEARNING LAB WITH THE ILLUSTRATION BELOW TO BECOME FAMILIAR WITH ITS MANY PARTS.



BRIEF EXPLANATIONS FOR THESE PARTS ARE ON THE NEXT PAGE. YOU WILL LEARN MUCH MORE ABOUT EACH PART AS YOU BUILD PROJECTS IN THIS MANUAL.

POWER SWITCH

THE POWER SWITCH APPLIES POWER TO THE BREADBOARD'S POWER OUTLETS (V1-V6).

LED DISPLAY

THE SEVEN-SEGMENT LED DISPLAY CAN PRODUCE THE DIGITS 0 THROUGH 9 PLUS SPECIAL LETTERS AND CHARACTERS. EACH LED SEGMENT INCLUDES A SERIES RESISTOR TO LIMIT CURRENT.

LEDS (10)

THE TEN LEDS ARE PERFECT FOR SOME OF THE DIGITAL PROJECTS IN MANUAL 2. EACH LED INCLUDES A 1,500-OHM CURRENT LIMITING RESISTOR.

TRANSFORMER

MANY CIRCUITS CANNOT DIRECTLY POWER A SPEAKER. BUT THEY CAN BE CONNECTED TO A SPEAKER THROUGH A TRANSFORMER.

METER

THE METER PERMITS VERY TINY CURRENTS TO BE MONITORED. THE METER CAN ALSO MEASURE VOLTAGE WITH THE HELP OF A RESISTOR.

PHOTORESISTOR

THE RESISTANCE OF A PHOTORESISTOR CHANGES WITH LIGHT. THIS ONE IS VERY SENSITIVE.

POTENTIOMETERS (3)

POTENTIOMETERS ARE ADJUSTABLE RESISTORS. THREE DIFFERENT RESISTANCE VALUES ARE INSTALLED ON YOUR CONSOLE TO PROVIDE TO PROVIDE DESIGN FLEXIBILITY.

DPDT SWITCH

THE DPDT (DOUBLE-POLE, DOUBLE-THROW) SWITCH IS A PAIR OF SPDT (SINGLE-POLE, DOUBLE-THROW) SWITCHES. MANY USES, INCLUDING CHANGING COMPONENT VALUES IN A CIRCUIT.

BREADBOARD

YOU WILL BUILD PROJECTS ON THE BREADBOARD, WHICH IS DESCRIBED IN DETAIL LATER.

PUSHBUTTON SWITCHES (4)

THE PUSHBUTTON SWITCHES ARE USED IN MANY PROJECTS. NORMALLY THEY ARE OPEN (OFF). WHEN PRESSED THEY ARE CLOSED (ON).

RELAY

THE RELAY IS A MECHANICAL SWITCH THAT IS CLOSED WHEN CURRENT IS SENT THROUGH A WIRE COIL. THOUGH VERY ANCIENT, RELAYS STILL HAVE MANY USES.

SPEAKER

THE SPEAKER TRANSFORMS A FLUCTUATING CURRENT INTO SOUND. IT CAN PRODUCE A MUCH WIDER RANGE OF AUDIO FREQUENCIES THAN A PIEZOELECTRIC DEVICE LIKE THE BUZZER.

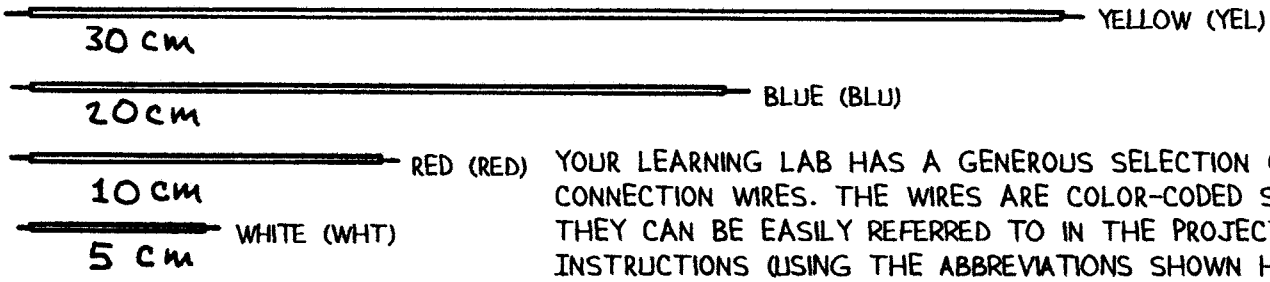
BUZZER

THE BUZZER PRODUCES A LOUD TONE AT A FREQUENCY OF ABOUT 1500 HERTZ. IT INCLUDES ITS OWN BUILT-IN TRANSISTOR OSCILLATOR.

PARTS SUPPLIED WITH YOUR ELECTRONICS LEARNING LAB

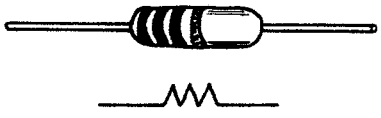
YOUR ELECTRONICS LEARNING LAB IS SUPPLIED WITH A GENEROUS ASSORTMENT OF COMPONENTS. CIRCUIT SYMBOLS AND GENERALIZED DRAWINGS OF EACH KIND OF PART ARE GIVEN BELOW. AVOID MISPLACING THE PARTS BY STORING THEM IN THE ORIGINAL PACKAGING OR IN CONTAINERS OF YOUR CHOICE. BE SURE TO STORE STATIC-SENSITIVE PARTS (POWER MOSFETS AND MOST INTEGRATED CIRCUITS) IN THE ORIGINAL PACKAGING OR IN ELECTRICALLY-CONDUCTIVE CONTAINERS. NEVER STORE SUCH PARTS IN STANDARD PLASTIC TRAYS OR BAGS.

CONNECTION WIRES



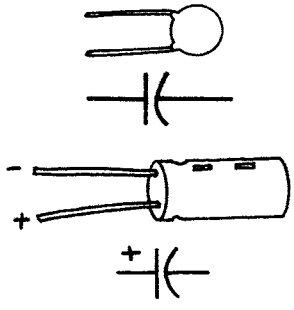
YOUR LEARNING LAB HAS A GENEROUS SELECTION OF CONNECTION WIRES. THE WIRES ARE COLOR-CODED SO THEY CAN BE EASILY REFERRED TO IN THE PROJECT INSTRUCTIONS (USING THE ABBREVIATIONS SHOWN HERE).

RESISTORS



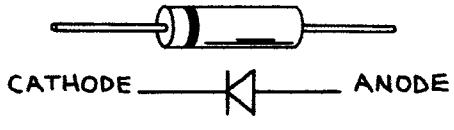
RESISTORS RESIST THE FLOW OF ELECTRICITY. THIS MAKES THEM VERY USEFUL FOR REDUCING CURRENT TO LIGHT-EMITTING DIODES, WHICH CAN BE DAMAGED BY TOO MUCH CURRENT. RESISTORS ARE ALSO USED TO DIVIDE A VOLTAGE INTO A SMALLER VOLTAGE. RESISTORS ARE USED TO INCREASE THE TIME REQUIRED TO CHARGE CAPACITORS AND SPEED UP THE DISCHARGE OF CAPACITORS. THEY ARE ALSO USED TO CONTROL THE GAIN OF AMPLIFIERS.

CAPACITORS



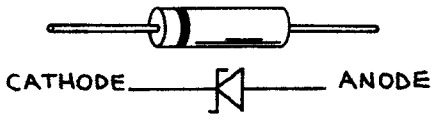
CAPACITORS STORE AN ELECTRICAL CHARGE. CAPACITORS SMOOTH A FLUCTUATING SIGNAL. THEY BLOCK CONTINUOUS CURRENT WHILE PASSING CURRENT PULSES. CAPACITORS IN SERIES WITH RESISTORS ARE USED IN CIRCUITS THAT MEASURE TIME OR GENERATE A SERIES OF PULSES. THEY ARE OFTEN USED WITH RESISTORS. CERAMIC DISK AND ELECTROLYTIC TYPES ARE THE MOST COMMON, WITH THE LATTER HAVING THE MOST CAPACITY.

SILICON DIODE



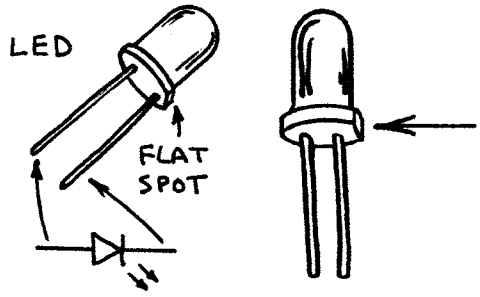
DIODES ARE ONE-WAY VALVES FOR ELECTRICAL CURRENT. CURRENT FLOWS ONE WAY BUT NOT THE OTHER. A DIODE IS ALSO A SWITCH, SINCE CURRENT WILL NOT FLOW UNTIL THE VOLTAGE EXCEEDS ABOUT 0.6 VOLT. THE DIODES PROVIDED WITH YOUR LEARNING LAB ARE MARKED 1N4148. SINCE DIODES ARE SMALL, THE MARKING MAY BE IN TWO OR THREE ROWS OF DIGITS. SOME DIODES MAY HAVE ONLY THE FOUR DIGITS (4148). A RING INDICATES THE CATHODE LEAD.

ZENER DIODE



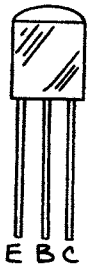
ZENER DIODES AND STANDARD DIODES ARE BOTH ONE-WAY VALVES FOR ELECTRICAL CURRENT. CURRENT FLOWS ONE WAY BUT NOT THE OTHER. BUT THE ZENER DIODE IS CONNECTED BACKWARDS. IT THEN BLOCKS CURRENT UNTIL THE VOLTAGE EXCEEDS A CERTAIN LEVEL. THE ZENER DIODE PROVIDED WITH YOUR LEARNING LAB TURNS ON AT 5 VOLTS. IT LOOKS MUCH LIKE THE STANDARD DIODES. A RING AROUND ONE END INDICATES THE CATHODE LEAD.

LIGHT-EMITTING DIODE (LED)



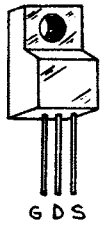
MOST LIGHT-EMITTING DIODES (LEDS) EMIT LIGHT OF ONE COLOR. YOUR LEARNING LAB INCLUDES TWO LOOSE LEDS (RED AND GREEN). THE CATHODE LEAD IS INDICATED BY A FLAT SPOT IN THE RIM AT THE BASE OF EACH DEVICE. A ROW OF 10 RED LEDS IS INSTALLED IN THE CONSOLE. LEDS MUST USUALLY BE CONNECTED TO A RESISTOR TO REDUCE CURRENT TO A SAFE VALUE. THE CONSOLE LEDS ARE EQUIPPED WITH RESISTORS FOR THIS PURPOSE.

BIPOLAR TRANSISTORS (PNP AND NPN)



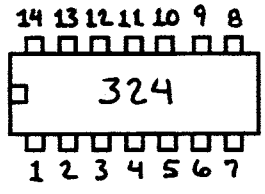
BIPOLAR TRANSISTORS ARE LIKE SWITCHES. CURRENT FLOWING BETWEEN THE COLLECTOR (C) AND EMITTER (E) CAN BE SWITCHED ON OR OFF BY A CURRENT AT THE BASE (B). TRANSISTORS CAN ALSO AMPLIFY BY ALLOWING A TINY, FLUCTUATING SIGNAL AT THE BASE TO CONTROL A MUCH LARGER CURRENT. YOUR LEARNING LAB HAS 2 NPN AND 2 PNP TRANSISTORS. THE PART NUMBERS FOR TRANSISTORS ARE USUALLY PRINTED ON THEIR FRONT SIDE. VARIOUS OTHER NUMBERS MAY ALSO BE PRESENT, SO JUST LOOK FOR THE PART NUMBERS.

POWER FIELD-EFFECT TRANSISTORS (MOSFETS)



METAL-OXIDE-SEMICONDUCTOR (MOS) FIELD-EFFECT TRANSISTORS (FETS) ARE THE COOLEST OF ALL TRANSISTORS. THEY MAKE EXCELLENT SWITCHES FOR CURRENT FLOWING BETWEEN THE SOURCE (S) AND DRAIN (D) SINCE THEY HAVE VERY LITTLE RESISTANCE WHEN TURNED ON BY A VOLTAGE AT THE GATE (G). THIS MEANS THEY CAN CONTROL MUCH MORE CURRENT THAN BIPOLAR TRANSISTORS. THEY CAN ALSO BE USED AS AMPLIFIERS. IMPORTANT: MOSFETS CAN BE DAMAGED BY STATIC ELECTRICITY.

INTEGRATED CIRCUITS

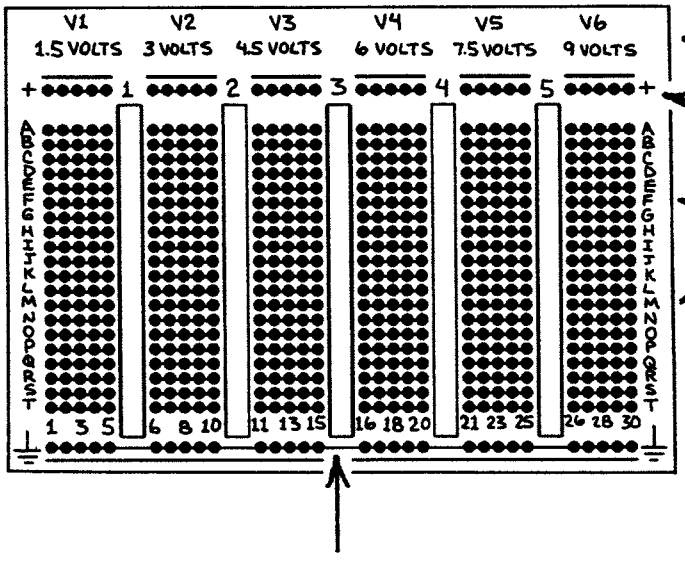


INTEGRATED CIRCUITS (ICS) ARE MICROSCOPIC ELECTRONIC CIRCUITS ETCHED ON A SLIVER OF SILICON CALLED A "CHIP" AND INSTALLED IN A PLASTIC, METAL OR CERAMIC PACKAGE WITH EXTERNAL LEADS OR PINS. AS SHOWN HERE, ONE END OF AN IC HAS AN INDEX MARKER (USUALLY A NOTCH OR CIRCLE) THAT IDENTIFIES PIN 1.

THE SOLDERLESS BREADBOARD

ELECTRICAL CONNECTION TO THE PARTS INSTALLED ON YOUR ELECTRONICS LEARNING LAB IS MADE POSSIBLE BY 69 SPRING TERMINALS. LOOSE PARTS ARE INSTALLED ON THE SOLDERLESS BREADBOARD. THE BREADBOARD HAS 660 CONNECTION POINTS. THIRTY OF THESE POINTS PROVIDE SIX DIFFERENT VOLTAGES FOR YOUR PROJECTS. YOU WILL INSERT CONNECTION WIRES AND THE LEADS AND PINS OF ELECTRONIC COMPONENTS INTO THE CONNECTION POINTS. THE BREADBOARD IS PERFECT FOR THE SIMPLEST PROJECTS USING ONLY A FEW PARTS. AND IT MAKES POSSIBLE COMPLICATED PROJECTS THAT USE INTEGRATED CIRCUITS.

HOW THE BREADBOARD IS ORGANIZED



THE LISTED VOLTAGES APPLY TO THE FIVE CONNECTION HOLES BELOW.

INSERT POSITIVE (+) POWER CONNECTION WIRES ALONG THIS ROW.

THE MAIN SECTION OF THE BOARD HAS 600 CONNECTION POINTS.

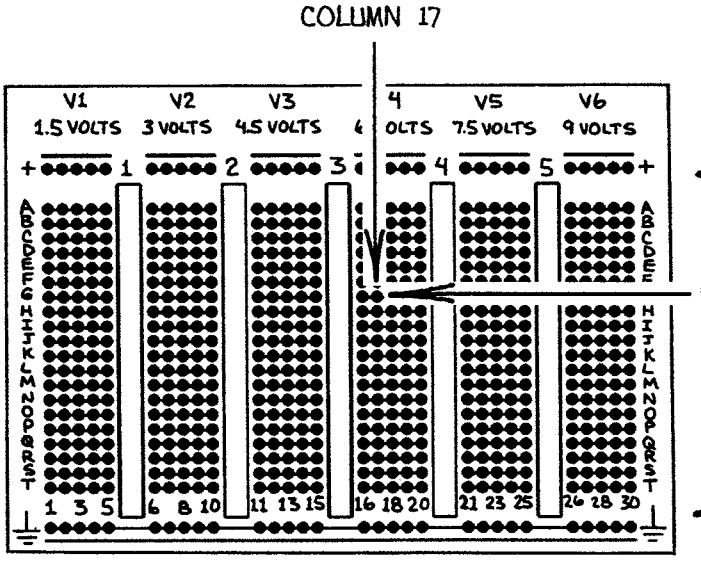
ALL 30 OF THESE CONNECTION POINTS GO TO GROUND, THE NEGATIVE (-) SIDE OF THE BATTERY PACK).

POWER IS DELIVERED TO THE SOLDERLESS BREADBOARD ONLY WHEN THE POWER SWITCH IS PUSHED TO "ON."

THE LINES THROUGH THE CONNECTION POINTS SHOW HOW THEY ARE ELECTRICALLY CONNECTED.

HOW THE BREADBOARD COORDINATE SYSTEM WORKS

EACH OF THE 600 CONNECTION POINTS ON THE BREADBOARD IS IDENTIFIED BY A COORDINATE SYSTEM BASED ON THE ROW AND COLUMN LABELS. ROWS ARE INDICATED BY LETTERS AND COLUMNS BY NUMBERS. THE ARROWS BELOW SHOW THE LOCATION OF CONNECTION POINT G17.



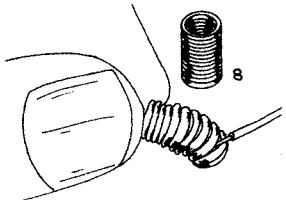
THE PROJECTS IN YOUR LEARNING LAB WILL ASK YOU TO CONNECT A WIRE TO ONE OR MORE OF THE SIX POSITIVE (+) VOLTAGES ALONG THE TOP OF THE BREADBOARD. YOU CAN USE ANY OF THE FIVE HOLES BELOW THE MARKED VOLTAGES. SOME PROJECTS ADD MORE + VOLTAGE CONNECTION POINTS BY RUNNING A WIRE DOWN TO A ROW ON THE MAIN PART OF THE BOARD.

USE ANY OF THE 30 CONNECTION POINTS ALONG THE BOTTOM OF THE BOARD FOR GROUND.

HOW TO ASSEMBLE CIRCUITS

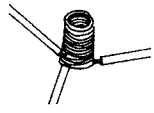
ELECTRICAL CONNECTION TO THE PARTS INSTALLED ON YOUR ELECTRONICS LEARNING LAB IS MADE POSSIBLE BY 69 SPRING TERMINALS. YOU WILL INSERT THE LOOSE PARTS PROVIDED WITH YOUR LEARNING LAB INTO THE SOLDERLESS BREADBOARD. YOU WILL USE CONNECTION WIRES TO CONNECT THE SPRINGS TO THE PARTS YOU INSTALL ON THE BREADBOARD.

INSERTING CONNECTION WIRES INTO THE SPRINGS

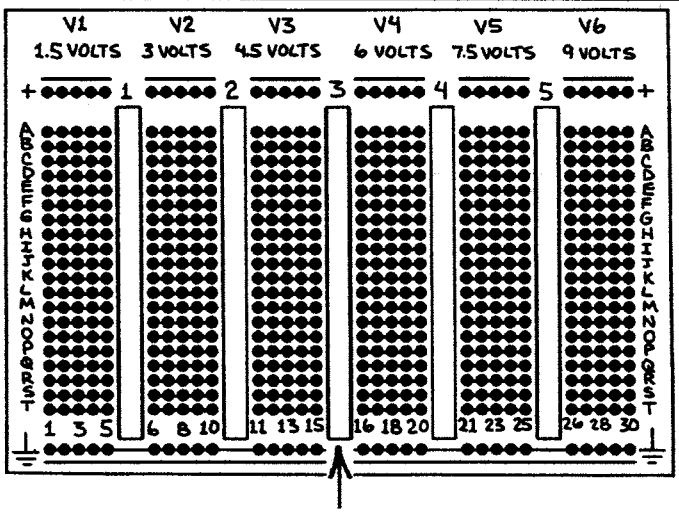


TO INSERT A CONNECTION WIRE INTO A SPRING, BEND THE SPRING SIDEWAYS AND INSERT THE EXPOSED METAL PORTION OF THE WIRE INTO AN OPEN SLOT NEAR THE BOTTOM OF THE SPRING. BE SURE THAT ONLY THE BARE METAL ENTERS THE SPRING. THEN ALLOW THE SPRING TO RETURN TO ITS NORMAL POSITION. BE SURE TO KEEP THE INSULATED PORTION OF THE WIRE OUTSIDE THE SPRING. REMOVE CONNECTION WIRES BY BENDING THE SPRING AWAY FROM THE WIRE. THEN PULL THE WIRE FREE.

YOU CAN INSERT SEVERAL WIRES INTO A SPRING TERMINAL. FOR BEST RESULTS INSERT WIRES ON OPPOSITE SIDES OF THE TERMINAL. BE SURE TO INSERT NEW WIRES AT DIFFERENT LEVELS WITHIN THE SPRING.

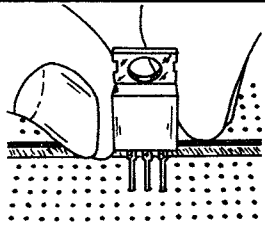


HOW TO INSERT PARTS AND WIRES INTO THE BREADBOARD



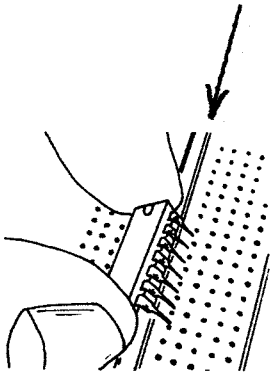
SLOT

INSERT A WIRE INTO A CONNECTION POINT BY PUSHING UNTIL IT STOPS. DO THE SAME WITH PARTS HAVING WIRE LEADS. PARTS WITH THICK LEADS OR PINS, SUCH AS THE TRANSISTOR SHOWN HERE, REQUIRE MORE FORCE. ALIGN THE PINS WITH THE PROPER HOLES AND THEN PRESS DOWN FIRMLY ON THE PART.



REMOVE PARTS AND WIRES BY CAREFULLY PULLING THEM STRAIGHT UP. PRY ICS UP FROM ONE END AND THEN THE OTHER.

INTEGRATED CIRCUITS (ICS) MUST BE INSTALLED ACROSS ONE OF THE FIVE SLOTS IN THE SOLDERLESS BREADBOARD. THE ICS SUPPLIED WITH YOUR LEARNING LAB HAVE TWO PARALLEL ROWS OF PINS. EACH ROW SHOULD BE INSERTED INTO THE CONNECTION POINTS ALONG OPPOSITE SIDES OF A SLOT. USE CARE TO AVOID BENDING PINS. CAUTION: IC PINS ARE SHARP!

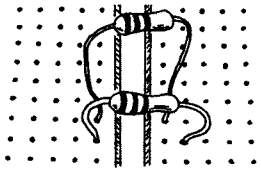


INSTALL AN IC BY LINING UP THE PINS ON ONE SIDE WITH THE CORRECT CONNECTION HOLES ALONG THE EDGE OF A SLOT. REST THE OPPOSITE SIDE OF THE IC ATOP THE PROPER HOLES ON THE OPPOSITE SIDE OF THE SLOT AND PRESS DOWN ON THE TOP OF THE IC. IF THE IC IS NEW, THE PINS WILL BE SPREAD SLIGHTLY OUTWARD. PRESS THE TIP OF A BALLPOINT PEN NEXT TO THE PIN FARTHEST AWAY FROM YOU. PUSH THE PEN TOWARD THE ROW OF CONNECTION HOLES WHILE PULLING IT ALONG THE ROW OF PINS. AT THE SAME TIME, PRESS DOWN ON THE IC. WHEN THE PEN REACHES THE LAST PIN, THE IC SHOULD SLIP DOWN INTO THE CONNECTION POINTS AND REST FLAT AGAINST THE BREADBOARD.

MORE ABOUT ASSEMBLY METHODS

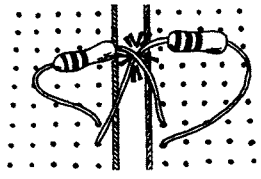
ALWAYS PUSH THE POWER SWITCH TO OFF BEFORE YOU ASSEMBLE A CIRCUIT. BE SURE TO INSTALL PARTS IN THE PROPER HOLES. A MISTAKE MIGHT VERY WELL "FRY" A COMPONENT WHEN YOU PUSH THE POWER SWITCH ON. IF AN INCORRECTLY INSTALLED PART SURVIVES, THE CIRCUIT WILL PROBABLY NOT WORK PROPERLY.

THESE TWO RESISTORS ARE INSTALLED CORRECTLY



BE SURE TO KEEP THE LEADS OF PARTS FROM TOUCHING ONE ANOTHER WHEN THEY ARE INSTALLED ON THE SOLDERLESS BREADBOARD. THESE TWO RESISTORS ARE INSERTED INTO THE BREADBOARD VERTICALLY. THEIR LEADS ARE SEPARATED FROM ONE ANOTHER AND DO NOT TOUCH.

THESE TWO RESISTORS ARE INSTALLED INCORRECTLY

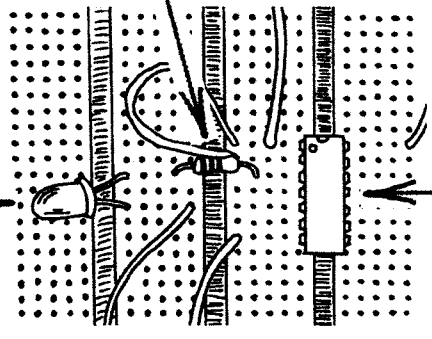


THESE TWO RESISTORS ARE INSTALLED IMPROPERLY. THE ONE ON THE LEFT IS PUSHED DOWN AND ONE OF ITS LEADS IS TOUCHING THE LEAD OF THE ADJACENT RESISTOR. THE CIRCUIT THEY ARE INSTALLED IN WILL NOT WORK PROPERLY--IF IT WORKS AT ALL.

WHAT'S RIGHT ABOUT THIS SAMPLE SOLDERLESS BREADBOARD CIRCUIT?

THIS RESISTOR IS INSTALLED ACROSS ONE OF THE SLOTS IN THE BREADBOARD, WHICH MEANS EACH LEAD GOES TO A SEPARATE CONNECTION ROW. OK.

THIS LED IS INSTALLED ACROSS SEPARATE CONNECTION ROWS. ONE ROW GOES TO A RESISTOR THAT LIMITS CURRENT TO THE LED. THE OTHER ROW GOES TO A LEAD THAT GOES OFF THE MODULE TO GROUND. GOOD.



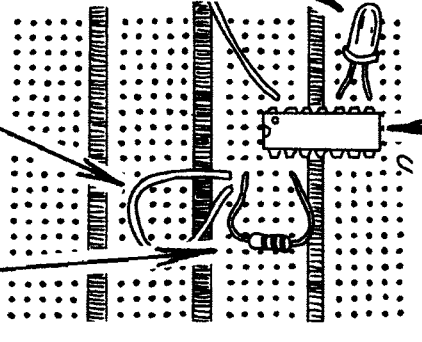
THIS INTEGRATED CIRCUIT IS INSTALLED ACROSS ONE OF THE SLOTS IN THE BREADBOARD. THIS MEANS EACH OF ITS PINS IS INSERTED INTO AN INDEPENDENT CONNECTION ROW. ALSO, EACH OF THE PINS ON THE IC ENTERS A CONNECTION HOLE AND NONE ARE BENT UNDER THE IC PACKAGE. CORRECT.

WHAT'S WRONG WITH THIS SAMPLE SOLDERLESS BREADBOARD CIRCUIT?

BOTH LEADS OF THIS LED ARE INSTALLED IN THE SAME CONNECTION ROW, THE LED WILL NOT WORK.

ONE END OF THIS WIRE IS CONNECTED TO A ROW THAT GOES NOWHERE.

BOTH LEADS OF THIS RESISTOR ARE IN THE SAME CONNECTION ROW. THE RESISTOR WILL NOT WORK.

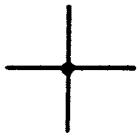
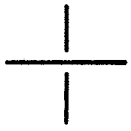
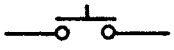
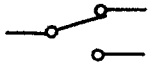
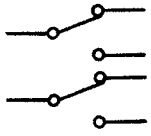
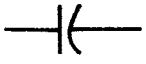
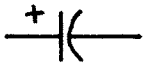
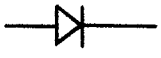
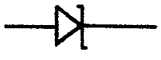
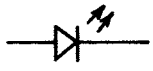
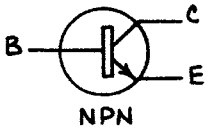
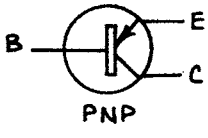
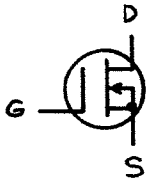
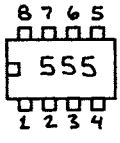
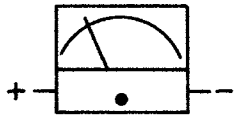
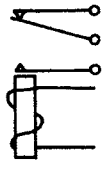
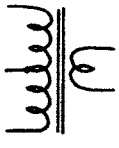
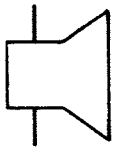
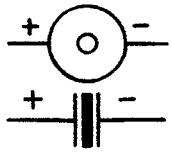


THIS INTEGRATED CIRCUIT IS INSTALLED ACROSS ONE OF THE SLOTS IN THE BREADBOARD. THE IC PINS DO NOT GO TO SEPARATE CONNECTION ROWS. AND TWO PINS ON EACH SIDE OF THE IC ARE BENT UNDER THE IC. THE IC MUST BE INSTALLED WITH ITS LONG SIDE PARALLEL WITH THE SLOT.

ELECTRONIC CIRCUIT SYMBOLS AND DIAGRAMS

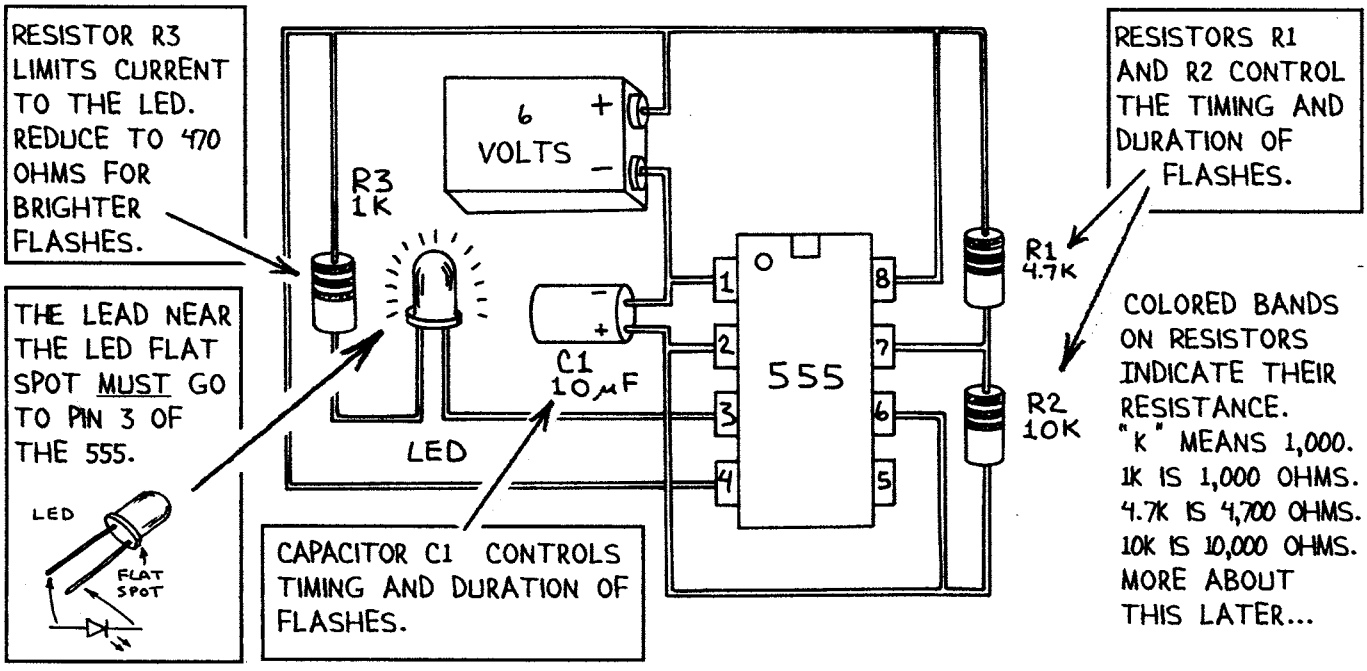
ON PAGES 8-9, VARIOUS SYMBOLS ARE SHOWN ALONGSIDE THE COMPONENTS THEY REPRESENT. THOSE AND ADDITIONAL CIRCUIT SYMBOLS ARE SHOWN HERE. ON PAGE 14 WE WILL USE SOME OF THESE SYMBOLS TO REPRESENT A CIRCUIT THAT FLASHES AN LED.

SCHEMATIC OR CIRCUIT DIAGRAM SYMBOLS

 CONNECTED WIRES	 UNCONNECTED WIRES	 PUSHBUTTON SWITCH (NORMALLY OPEN)	 SPDT (SINGLE POLE, DOUBLE THROW) SWITCH	 DPDT (DOUBLE POLE, DOUBLE THROW) SWITCH
 POSITIVE (+) VOLTAGE CONNECTION	 GROUND CONNECTION	 RESISTOR	 POTENTIOMETER (VARIABLE RESISTOR)	 PHOTORESISTOR (LIGHT-SENSITIVE RESISTOR)
 CERAMIC CAPACITOR	 ELECTROLYTIC CAPACITOR	 DIODE	 ZENER DIODE	 LIGHT-EMITTING DIODE (LED)
 NPN BIPOLAR TRANSISTOR	 PNP BIPOLAR TRANSISTOR	 POWER MOSFET TRANSISTOR	 INTEGRATED CIRCUIT	 METER
 RELAY	 TRANSFORMER	 MAGNETIC SPEAKER	 PIEZOELECTRIC BUZZER	VARIOUS OTHER SYMBOLS FOR INTEGRATED CIRCUITS AND DIGITAL LOGIC ARE INTRODUCED LATER.

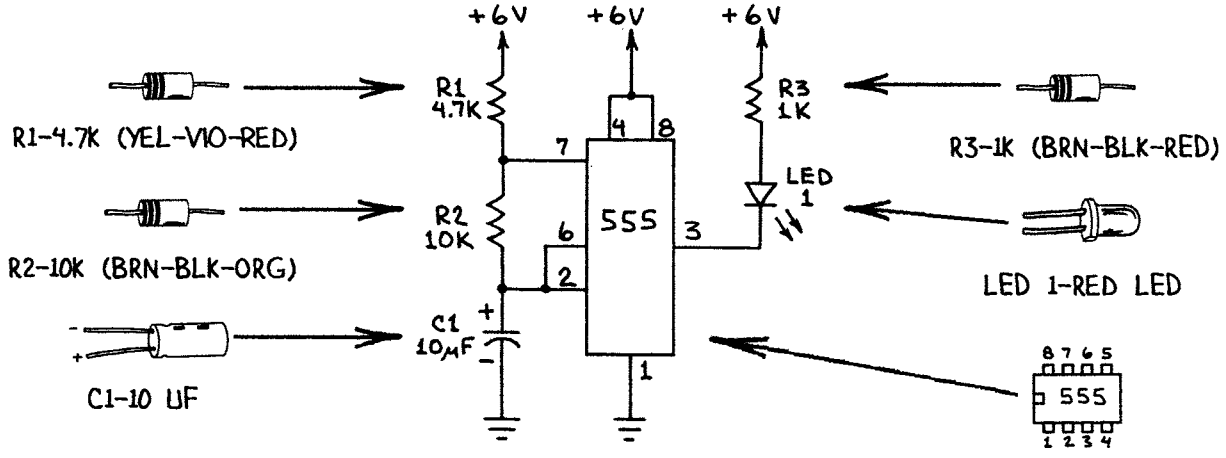
GETTING STARTED: A PICTORIAL VIEW OF A CIRCUIT THAT FLASHES AN LED

THE ILLUSTRATION BELOW IS A PICTORIAL VIEW OF A CIRCUIT THAT USES A 555 INTEGRATED CIRCUIT TO SEND PULSES OF CURRENT TO A RED LIGHT-EMITTING DIODE. PICTORIAL VIEWS ARE VERY CLEAR, BUT THEY ARE NOT PRACTICAL FOR COMPLICATED CIRCUITS. CIRCUIT DIAGRAMS IN WHICH ELECTRONIC PARTS ARE REPRESENTED BY THE SYMBOLS ON THE FACING PAGE ARE MUCH MORE COMMONLY USED.



A CIRCUIT DIAGRAM OF A CIRCUIT THAT FLASHES AN LED

THE CIRCUIT DIAGRAM BELOW IS EQUIVALENT TO THE PICTORIAL VIEW ABOVE. THE SAME CIRCUIT IS SHOWN IN BOTH DIAGRAMS. THE MOST IMPORTANT DIFERENCE BETWEEN THE TWO DRAWINGS IS THAT IN THE CIRCUIT DIAGRAM THE PINS OF THE 555 IC ARE NOT SHOWN IN THE SAME ARRANGEMENT THEY HAVE ON THE ACTUAL IC. THIS SHORTCUT PROVIDES A SIMPLER WAY OF REPRESENTING THE CIRCUIT. NOTE THAT THE 6-VOLT BATTERY IS REPLACED BY SYMBOLS.

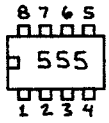


COMPARE THE TWO CIRCUITS BY CHECKING TO SEE IF THE SAME CONNECTIONS ARE MADE TO EACH 555 PIN. START AT PIN 1. (PIN 5 IS NOT USED.) THIS IS AN EXCELLENT WAY TO FIND MISTAKES WHEN YOU BUILD CIRCUITS ON YOUR LEARNING LAB'S BREADBOARD. THE RESISTORS ARE MARKED WITH A CODE OF COLORED BANDS (YEL = YELLOW, VIO = VIOLET, BRN = BROWN, ORG = ORANGE AND BLK = BLACK). LATER WE WILL COVER HOW TO INTERPRET THIS CODE.

GETTING STARTED: BUILD A SIMPLE LED FLASHER

NOW YOU ARE READY TO BUILD THE LED FLASHER CIRCUIT ON PAGE 14. BUILDING THIS CIRCUIT WILL HELP PREPARE YOU TO BUILD ALL THE CIRCUITS DESCRIBED IN YOUR LEARNING LAB MANUALS. TIP: CIRCUIT BUILDING GOES MUCH FASTER IF YOU FIRST GATHER TOGETHER ALL THE PARTS YOU WILL NEED. ALSO, BE SURE TO REMOVE UNUSED PARTS FROM THE BREADBOARD.

PARTS YOU WILL NEED



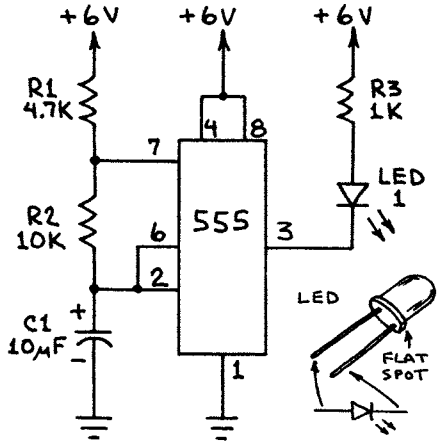
R1-4.7K (YEL-VIO-RED)
R2-10K (BRN-BLK-ORG)
R3-1K (BRN-BLK-RED)

C1-10 UF

LED 1-RED LED

CIRCUIT DIAGRAM

THE CIRCUIT SPECIFIES A RED LED FOR LED 1. YOU CAN USE A GREEN LED IF YOU PREFER.



HOW IT WORKS

THIS CIRCUIT IS A BASIC ASTABLE OR FREE-RUNNING PULSE GENERATOR. THE PULSE RATE IS DETERMINED PRIMARILY BY C1 AND THE RESISTORS THROUGH WHICH C1 CHARGES (R1 AND R2). THE WIDTH OF THE PULSES IS CONTROLLED BY R2. R3 LIMITS CURRENT THROUGH THE LED TO A SAFE VALUE. NOTICE HOW ALL THE CONNECTIONS TO +6 VOLTS ARE SHOWN SEPARATELY. THIS STYLE IS USED IN MOST OF YOUR LEARNING LAB CIRCUIT DIAGRAMS.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT THE 555 IC ACROSS SLOT 3 (PIN 1 AT F15).
3. ☐ CONNECT I14 TO F17 (WHT WIRE).
4. ☐ CONNECT G14 TO H17 (WHT WIRE).
5. ☐ CONNECT F20 TO V4 (+6V) (WHT WIRE).
6. ☐ CONNECT F13 TO GROUND (RED WIRE).
7. ☐ INSERT R1 ACROSS G19 AND V4 (+6V).
8. ☐ INSERT R2 ACROSS G20 AND H20.
9. ☐ INSERT R3 ACROSS D15 AND V4 (+6V).
10. ☐ INSERT LED 1 ACROSS D13 (ANODE) AND H13 (CATHODE).
11. ☐ INSERT C1 ACROSS G11 (+) AND F11 (-).

2. TEST THE CIRCUIT

CHECK THE CIRCUIT FOR ERRORS. WHEN YOU ARE SURE ALL THE WIRES AND COMPONENTS ARE INSTALLED CORRECTLY, PUSH THE POWER SWITCH UP (ON). THE LED SHOULD BEGIN FLASHING SEVERAL TIMES PER SECOND. PROBLEM? GO TO PAGES 16 AND 18 FOR HELP.

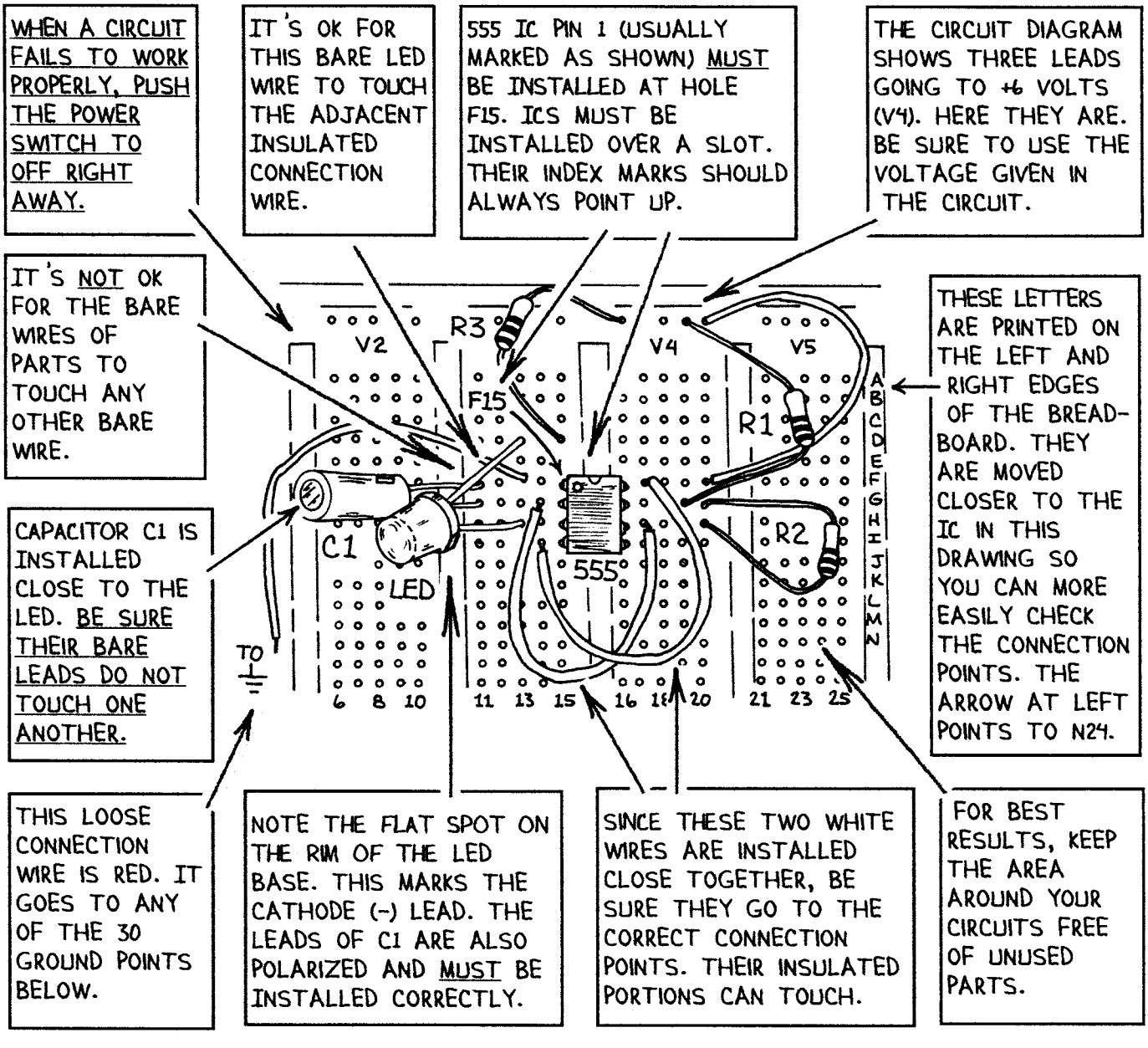
GOING FURTHER

THIS SIMPLE CIRCUIT IS EASY TO MODIFY. TO SLOW THE FLASH RATE TO ABOUT ONCE EVERY TWO SECONDS, INSERT A 100 UF CAPACITOR ACROSS C1 AT G12 (+) AND F12 (-). TO TRIGGER A SHRILL TONE FROM THE BUZZER EACH TIME THE LED SWITCHES ON, USE BLUE WIRES TO CONNECT SPRING 67 TO H11 AND SPRING 66 TO V4 (+6V). THE 555 TIMER IS AMAZINGLY VERSATILE. MORE APPLICATIONS FOR THE 555 ARE GIVEN LATER IN THIS MANUAL. BE SURE TO COMPARE YOUR CIRCUIT WITH THE PICTORIAL VIEW ON PAGE 16. YOU WILL FIND SOME TIPS THAT WILL HELP YOU BUILD THIS AND OTHER CIRCUITS.

GETTING STARTED: CHECKING OUT THE CIRCUIT

IF YOU ADDED THE 100 UF CAPACITOR, YOUR LED FLASHER CIRCUIT SHOULD NOW BE FLASHING SEVERAL TIMES EACH SECOND. OR MAYBE IT'S NOT WORKING. EITHER WAY, COMPARE YOUR CIRCUIT WITH THE ONE BELOW TO SEE WHAT YOU DID RIGHT—OR WHAT YOU DID WRONG.

FINDING AND CORRECTING ERRORS IN ELECTRONIC CIRCUITS IS CALLED "TROUBLESHOOTING." TROUBLESHOOTING IS COVERED ON PAGE 18. YOU WILL GET A GOOD IDEA OF WHAT'S INVOLVED IN TROUBLESHOOTING YOUR LEARNING LAB PROJECTS BY COMPARING YOUR CIRCUIT WITH THE ILLUSTRATION BELOW.



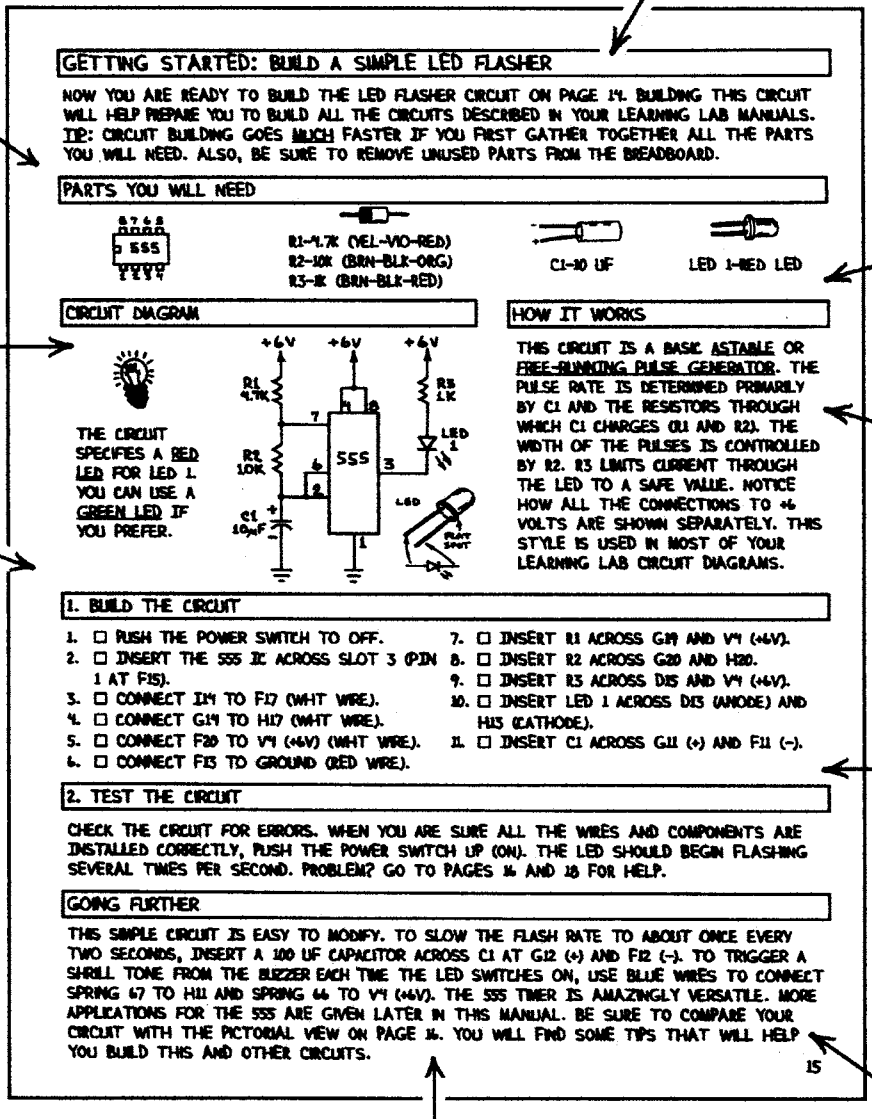
TO PROTECT YOUR LEARNING LAB, AND FOR BEST RESULTS, ALWAYS SWITCH THE POWER SWITCH TO OFF BEFORE BUILDING OR MODIFYING A CIRCUIT. AFTER YOU BUILD A CIRCUIT, CAREFULLY CHECK FOR ERRORS BEFORE SWITCHING THE POWER BACK ON.

GETTING STARTED: REVIEW WHAT YOU HAVE LEARNED

YOU CAN BUILD THE CIRCUITS IN THIS MANUAL IN ORDER OR RANDOMLY. SO YOU CAN QUICKLY LEARN HOW THE PROJECTS ARE PRESENTED, BEGIN WITH THE 555 LED FLASHER ON PAGE 15. THE EXPLANATIONS BELOW SHOW HOW THIS AND MOST OTHER PROJECT PAGES IN YOUR TWO LEARNING LAB MANUALS ARE ORGANIZED. WHILE DETAILED ASSEMBLY INSTRUCTIONS ARE PROVIDED WITH EACH PROJECT, EVENTUALLY YOU WILL BE ABLE TO BUILD THE CIRCUITS STRAIGHT FROM THE CIRCUIT DIAGRAMS. TIP: BE SURE TO COLLECT ALL THE PARTS BEFORE STARTING A CIRCUIT.

"PARTS YOU WILL NEED" LISTS ALL PARTS EXCEPT WIRES AND THOSE ON THE CONSOLE.

EACH PROJECT PAGE HAS A TITLE BAR THAT DESCRIBES THE PROJECT. A BRIEF INTRODUCTION BELOW THE TITLE BAR EXPLAINS WHAT YOU WILL DO AND LEARN.



GETTING STARTED: BUILD A SIMPLE LED FLASHER

NOW YOU ARE READY TO BUILD THE LED FLASHER CIRCUIT ON PAGE 14. BUILDING THIS CIRCUIT WILL HELP PREPARE YOU TO BUILD ALL THE CIRCUITS DESCRIBED IN YOUR LEARNING LAB MANUALS. TIP: CIRCUIT BUILDING GOES MUCH FASTER IF YOU FIRST GATHER TOGETHER ALL THE PARTS YOU WILL NEED. ALSO, BE SURE TO REMOVE UNUSED PARTS FROM THE BREADBOARD.

PARTS YOU WILL NEED

555

R1-4.7K (YEL-VIO-RED)
R2-10K (BRN-BLK-ORG)
R3-1K (BRN-BLK-RED)

C1-10 UF

LED 1-RED LED

CIRCUIT DIAGRAM

THE CIRCUIT SPECIFIES A RED LED FOR LED 1. YOU CAN USE A GREEN LED IF YOU PREFER.

+6V +6V +6V
R1 4.7K
R2 10K
C1 10 uF
555
R3 1K
LED 1
LED

HOW IT WORKS

THIS CIRCUIT IS A BASIC ASTABLE OR FREE-RUNNING PULSE GENERATOR. THE PULSE RATE IS DETERMINED PRIMARILY BY C1 AND THE RESISTORS THROUGH WHICH C1 CHARGES (R1 AND R2). THE WIDTH OF THE PULSES IS CONTROLLED BY R2. R3 LIMITS CURRENT THROUGH THE LED TO A SAFE VALUE. NOTICE HOW ALL THE CONNECTIONS TO +6 VOLTS ARE SHOWN SEPARATELY. THIS STYLE IS USED IN MOST OF YOUR LEARNING LAB CIRCUIT DIAGRAMS.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT THE 555 IC ACROSS SLOT 3 (PIN 1 AT F15).
3. ☐ CONNECT I14 TO F17 (WHT WIRE).
4. ☐ CONNECT G19 TO H17 (WHT WIRE).
5. ☐ CONNECT F20 TO V9 (+6V) (WHT WIRE).
6. ☐ CONNECT F13 TO GROUND (RED WIRE).
7. ☐ INSERT R1 ACROSS G19 AND V9 (+6V).
8. ☐ INSERT R2 ACROSS G20 AND H20.
9. ☐ INSERT R3 ACROSS D15 AND V9 (+6V).
10. ☐ INSERT LED 1 ACROSS D13 (ANODE) AND H13 (CATHODE).
11. ☐ INSERT C1 ACROSS G11 (+) AND F11 (-).

2. TEST THE CIRCUIT

CHECK THE CIRCUIT FOR ERRORS. WHEN YOU ARE SURE ALL THE WIRES AND COMPONENTS ARE INSTALLED CORRECTLY, PUSH THE POWER SWITCH UP (ON). THE LED SHOULD BEGIN FLASHING SEVERAL TIMES PER SECOND. PROBLEM? GO TO PAGES 16 AND 18 FOR HELP.

GOING FURTHER

THIS SIMPLE CIRCUIT IS EASY TO MODIFY. TO SLOW THE FLASH RATE TO ABOUT ONCE EVERY TWO SECONDS, INSERT A 100 UF CAPACITOR ACROSS C1 AT G12 (+) AND F12 (-). TO TRIGGER A SHRILL TONE FROM THE BUZZER EACH TIME THE LED SWITCHES ON, USE BLUE WIRES TO CONNECT SPRING 67 TO H11 AND SPRING 66 TO V9 (+6V). THE 555 TIMER IS AMAZINGLY VERSATILE. MORE APPLICATIONS FOR THE 555 ARE GIVEN LATER IN THIS MANUAL. BE SURE TO COMPARE YOUR CIRCUIT WITH THE PICTORIAL VIEW ON PAGE 16. YOU WILL FIND SOME TIPS THAT WILL HELP YOU BUILD THIS AND OTHER CIRCUITS.

15

"CIRCUIT DIAGRAM" IS A SCHEMATIC DIAGRAM OF THE CIRCUIT YOU WILL BUILD.

BRIGHT IDEAS... WHEN SPACE PERMITS.

"HOW IT WORKS" IS INCLUDED WHEN SPACE PERMITS.

"BUILD THE CIRCUIT" GIVES STEP-BY-STEP INSTRUCTIONS. EVENTUALLY YOU WILL BE ABLE TO BUILD THE CIRCUITS BY FOLLOWING THE CIRCUIT DIAGRAM. THE FIRST STEP IS ALWAYS THE SAME.

CONNECTION WIRES ARE ABBREVIATED:

WHT = WHITE
RED = RED
BLU = BLUE
YEL = YELLOW

"TEST THE CIRCUIT" REMINDS YOU TO REVIEW YOUR WIRING FOR ERRORS BEFORE PUSHING THE POWER SWITCH ON.

THIS GENERAL PAGE LAYOUT IS USED TO PRESENT MOST PROJECTS IN BOTH THE MANUALS PROVIDED WITH YOUR LEARNING LAB. THE MAJOR EXCEPTION IS THE 555 IC "BLACK BOX" TEST CIRCUIT DESCRIBED ON PAGE 19. THIS CIRCUIT IS SHOWN ONCE IN DETAIL. LATER IT IS SHOWN AS A SIMPLE BOX TO AVOID REPETITION AND SAVE SPACE.

WHEN THERE IS SPACE, "GOING FURTHER" DESCRIBES WAYS TO MODIFY THE CIRCUIT.

TROUBLESHOOTING PROBLEM CIRCUITS

YOUR CIRCUITS SHOULD WORK THE FIRST TIME YOU PUSH THE POWER SWITCH ON IF YOU FOLLOW THE STEP-BY-STEP INSTRUCTIONS, USE THE CORRECT PARTS, AND DON'T BECOME RUSHED. BUT SOMETIMES A CIRCUIT WILL NOT WORK PROPERLY. WHILE THIS CAN BE FRUSTRATING, IT'S A ROUTINE PART OF EXPERIMENTING WITH ELECTRONIC CIRCUITS. HERE'S HOW TO TROUBLESHOOT A PROBLEM CIRCUIT:

1. PUSH THE POWER SWITCH TO THE OFF POSITION.

2. BE SURE BATTERIES ARE INSTALLED IN THE CONSOLE. CHECK TO MAKE SURE THEY ARE INSTALLED IN THE CORRECT DIRECTION AND THAT THEY ARE FRESH.

3. BE SURE THAT EXPOSED WIRE LEADS DO NOT TOUCH ONE ANOTHER.

4. THE WIRE CONNECTION LEADS CAN WORK LOOSE. BE SURE ALL THE LEADS ARE FULLY INSERTED INTO THE BREADBOARD.

5. CHECK TO MAKE SURE YOU DIDN'T LEAVE OUT A PART OR WIRE. (THIS WON'T HAPPEN IF YOU COLLECT ALL THE PARTS <u>BEFORE</u> YOU BUILD THE CIRCUIT.)

6. MAKE SURE YOU INSTALLED THE CORRECT PARTS. DOUBLE CHECK PART NUMBERS AND RESISTOR COLOR CODES (RED CAN LOOK LIKE ORANGE). IF THE NUMBERS ON DIODES, TRANSISTORS AND ICS ARE HARD TO READ, HOLD THE PART UNDER A BRIGHT LIGHT.

7. DIODES, TRANSISTORS AND INTEGRATED CIRCUITS <u>MUST</u> BE INSTALLED WITH THE LEADS OR PINS IN A SPECIFIC DIRECTION. BE SURE NONE OF THESE PARTS ARE INSTALLED BACKWARDS.

8. DIGITAL LOGIC ICS ARE CMOS DEVICES. ALL THEIR UNUSED INPUTS MUST BE CONNECTED TO GROUND OR THE POSITIVE POWER SUPPLY (+ VOLTAGE). A CIRCUIT MAY WORK IF YOU DON'T DO THIS. BUT UNCONNECTED INPUTS ACT LIKE TINY ANTENNAS THAT CAN SWITCH LOGIC CHIPS OFF AND ON. THIS CAN CAUSE ERRATIC OPERATION AND EXCESSIVE CURRENT DRAIN.

9. FREQUENTLY USED MECHANICAL PARTS, LIKE THE CONSOLE SWITCHES AND POTENTIOMETERS, TEND TO FAIL BEFORE COMPONENTS WITHOUT MOVING PARTS. IF A CIRCUIT DOESN'T RESPOND WHEN YOU PRESS A SWITCH OR TURN A KNOB, TRY BYPASSING THE SWITCH OR POT. BYPASS A SWITCH BY SQUEEZING ITS CONTACT SPRINGS TOGETHER. IF A POTENTIOMETER DOESN'T WORK, TRY USING ANOTHER POT. OR SUBSTITUTE ONE OR TWO RESISTORS FOR THE POT.

10. IF YOU TOOK SHORTCUTS OR MADE CHANGES TO A CIRCUIT, TRY REBUILDING THE CIRCUIT EXACTLY AS SHOWN IN THE CIRCUIT DIAGRAM. MAKE CHANGES AFTER THE CIRCUIT IS WORKING.

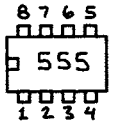
11. IF THE CIRCUIT STILL FAILS TO WORK, CHECK THE CONNECTIONS OF EACH PIN OR LEAD AGAINST THE CIRCUIT DIAGRAM. IF THE CIRCUIT USES AN IC, CHECK THE CONNECTIONS TO EACH PIN. BEGIN AT PIN 1 AND WORK AROUND THE CHIP PIN BY PIN. YOU WILL QUICKLY FIND MISSING OR INCORRECTLY INSTALLED WIRES AND PARTS.

12. OFTEN YOU CAN FIX A CIRCUIT FASTER BY REBUILDING IT THAN BY TRYING TO FIND A WIRING ERROR. AS A LAST RESORT, REMOVE <u>ALL</u> THE WIRES AND PARTS, MAKE SURE ALL THE PARTS ARE THE CORRECT ONES AND START OVER. IF THE CIRCUIT STILL FAILS, A PART MAY BE BAD. TRY USING A SUSPECT TRANSISTOR OR IC IN A DIFFERENT CIRCUIT. IF THAT CIRCUIT FAILS TO WORK, THE TRANSISTOR OR IC MAY BE BAD.

BUILD A 555 "BLACK BOX" TEST CIRCUIT

A "BLACK BOX" CIRCUIT IS ONE THAT'S THERE WHEN YOU NEED IT. YOU CAN USE IT EVEN IF YOU DON'T KNOW HOW IT WORKS. THIS "BLACK BOX" TEST CIRCUIT PRODUCES A TONE WITH A FREQUENCY CONTROLLED BY A RESISTOR AND A CAPACITOR. IT WILL HELP YOU UNDERSTAND HOW RESISTORS AND CAPACITORS WORK ON THEIR OWN AND TOGETHER.

PARTS YOU WILL NEED

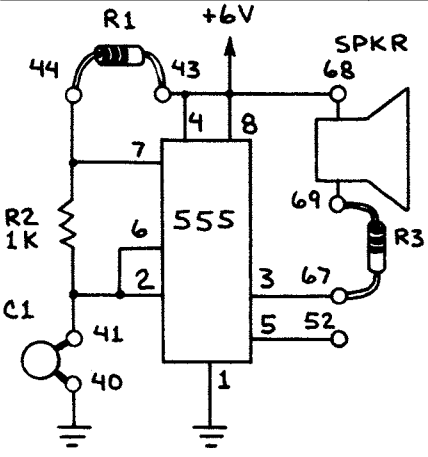


R1-10K (BRN-BLK-ORG)
R2-1K (BRN-BLK-RED)
R3-100 (BRN-BLK-BRN)

C1-0.1 UF (104)

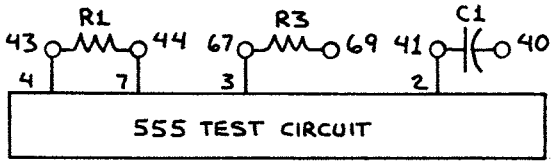
YOU WILL INSTALL R1, R3 AND C1 WHEN YOU USE THE CIRCUIT FOR VARIOUS TESTS.

CIRCUIT DIAGRAM



THE NUMBERED CIRCLES ARE SPRINGS ON YOUR CONSOLE. THE SPRINGS ARE BORROWED FROM UNUSED PARTS. BE SURE THAT THE DPDT SWITCH IS PUSHED DOWN. FOR TEST PURPOSES, THE CIRCUIT CAN BE SHOWN AS A BOX WITH EXTERNAL CONNECTIONS LIKE THIS: →

LEAVE THIS CIRCUIT ON THE BREADBOARD WHILE YOU BUILD THE SWITCH, RESISTOR AND CAPACITOR CIRCUITS ON THE FOLLOWING PAGES. SWITCH THE TONE OFF BY REMOVNG THE RED WIRE AT V4 (+6V) UNTIL NEEDED.



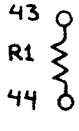
1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT THE 555 IC ACROSS SLOT 3 (PIN 1 AT F15).
3. ☐ CONNECT I14 TO F17 (WHT WIRE).
4. ☐ CONNECT G14 TO H17 (WHT WIRE).
5. ☐ CONNECT F11 TO GROUND (RED WIRE).
6. ☐ CONNECT F20 TO V4 (+6V) (RED WIRE).
7. ☐ INSERT R2 ACROSS G20 AND H20.
8. ☐ CONNECT SPRING 40 TO GROUND (WHT WIRE).
9. ☐ CONNECT SPRING 41 TO G11 (BLU WIRE).
10. ☐ CONNECT SPRING 43 TO I11 (RED WIRE).
11. ☐ CONNECT SPRING 44 TO G17 (BLU WIRE).
12. ☐ CONNECT SPRING 68 TO F18 (BLU WIRE).
13. ☐ CONNECT SPRING 67 TO H11 (BLU WIRE).
14. ☐ CONNECT SPRING 52 TO I20 (RED WIRE).
15. ☐ INSERT R1 ACROSS SPRINGS 43 AND 44.
16. ☐ INSERT R3 ACROSS SPRINGS 67 AND 69.
17. ☐ INSERT C1 ACROSS SPRINGS 40 AND 41.

2. TEST THE CIRCUIT

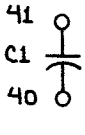
CHECK THE CIRCUIT FOR ERRORS. WHEN YOU ARE SURE EVERYTHING IS INSTALLED CORRECTLY, PUSH THE POWER SWITCH ON. THE SPEAKER WILL EMIT A TONE. NOW TRY THESE TESTS:

3. RESISTOR TEST



REMOVE R1. THE TONE WILL STOP. NOW REPLACE R1 WITH A 100K RESISTOR (BRN-BLK-YEL). THE SOUND WILL NOW RETURN AS A BUZZ. LEAVE THE NEW R1 IN PLACE AND TRY THE CAPACITOR TEST.

4. CAPACITOR TEST

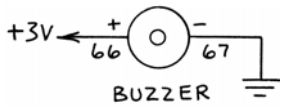


REMOVE C1. THE BUZZ WILL STOP. NOW REPLACE C1 WITH A 0.01 UF CAPACITOR (103). THE SOUND WILL AGAIN BE A TONE. THE NEW TONE WILL HAVE A HIGHER FREQUENCY THAN WHEN YOU USED THE ORIGINAL VALUES FOR R1 AND C1.

SWITCHES AND HOW TO USE THEM

YOUR ELECTRONICS LEARNING LAB HAS TWO SLIDE SWITCHES AND FOUR PUSHBUTTON SWITCHES. YOU WILL LEARN HOW TO USE BOTH KINDS OF SWITCHES.

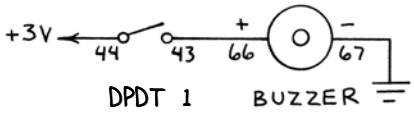
1. USING THE MAIN POWER SWITCH



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRING 66 TO V2 (+3V) (BLU WIRE).
3. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).

THIS SIMPLE DEMONSTRATION SHOWS HOW THE POWER SWITCH CONTROLS POWER TO THE BREADBOARD. PUSH THE POWER SWITCH ON AND THE BUZZER WILL SOUND.

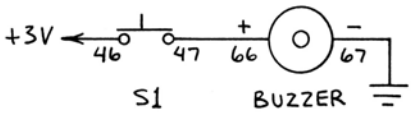
2. USE THE DPDT SWITCH TO ACTUATE THE BUZZER



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRINGS 43 AND 66 (BLU WIRE).
3. ☐ CONNECT SPRING 44 TO V2 (+3V) (BLU WIRE).
4. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).

THIS CIRCUIT USES 1/4 OF THE DPDT SLIDE SWITCH TO CONTROL THE BUZZER. PUSH THE POWER SWITCH ON AND THEN PUSH THE DPDT SWITCH UP TO SOUND THE BUZZER.

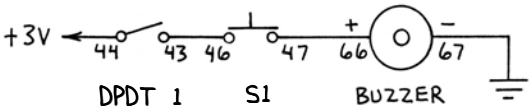
3. USE A PUSHBUTTON SWITCH TO ACTUATE THE BUZZER



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRINGS 47 AND 66 (BLU WIRE).
3. ☐ CONNECT SPRING 46 TO V2 (+3V) (BLU WIRE).
4. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).

THIS CIRCUIT USES A PUSHBUTTON SWITCH TO CONTROL THE BUZZER. PUSH THE POWER SWITCH UP. PRESS S1 TO SOUND THE BUZZER.

4. USE THE DPDT SWITCH AND A PUSHBUTTON SWITCH TO ACTUATE THE BUZZER

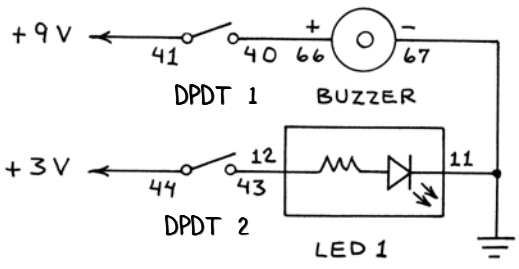


MODIFY THE CIRCUIT ABOVE:

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ MOVE BLUE WIRE AT V2 TO SPRING 43.
3. ☐ CONNECT SPRING 44 TO V2 (+3V) (BLU WIRE).

OFTEN TWO OR MORE SWITCHES ARE WIRED TOGETHER. THIS CIRCUIT ACTUATES THE BUZZER WHEN THE MAIN POWER SWITCH, THE PUSHBUTTON AND THE DPDT SLIDE SWITCH ARE CLOSED.

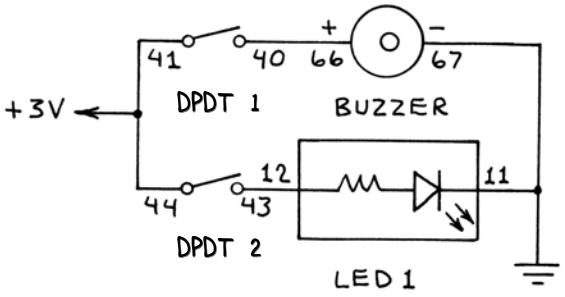
5. USE THE DPDT SWITCH TO ACTUATE TWO DEVICES AT DIFFERENT VOLTAGES



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRINGS 40 AND 66 (YEL WIRE).
3. ☐ CONNECT SPRING 41 TO V6 (+9V) (BLU WIRE).
4. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).
5. ☐ CONNECT SPRINGS 43 AND 12 (BLU WIRE).
6. ☐ CONNECT SPRING 44 TO V2 (+3V) (BLU WIRE).
7. ☐ CONNECT SPRING 11 TO GROUND (BLU WIRE).

PUSH THE POWER AND DPDT SWITCHES UP TO CONTROL TWO DEVICES AT THE SAME TIME.

6. USE THE DPDT SWITCH TO ACTUATE TWO DEVICES AT THE SAME VOLTAGE



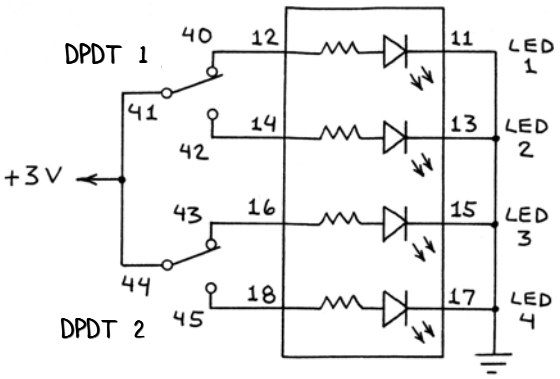
MODIFY THE PREVIOUS CIRCUIT:

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ MOVE BLU WIRE AT V6 (+9V) TO V2 (+3V).

CHECK FOR ERRORS AND PUSH THE POWER SWITCH ON. PUSH THE DPDT SWITCH UP TO CONTROL TWO DEVICES AT THE SAME VOLTAGE.

THIS IS A GOOD PLACE TO POINT OUT THAT YOU CAN MAKE CHANGES TO THE VOLTAGE OF SOME CIRCUITS. THIS CIRCUIT, FOR EXAMPLE, WILL WORK FINE WHEN POWERED BY +6 VOLTS. WATCH FOR MORE NOTES ABOUT POWER SUPPLY VOLTAGES.

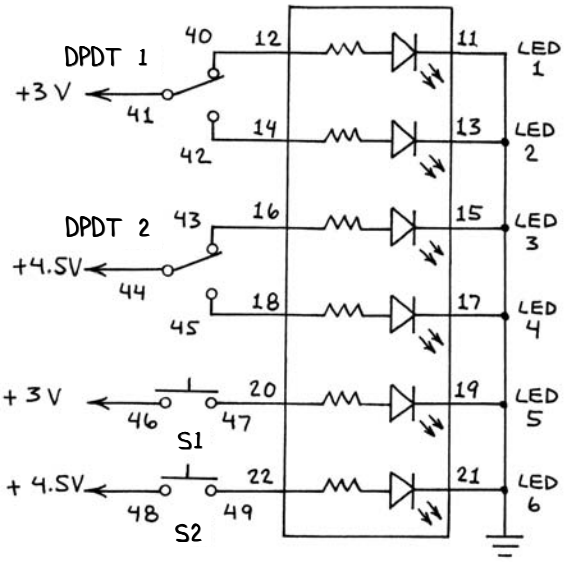
7. CONTROL FOUR LEDS WITH THE DPDT SWITCH



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRINGS 12 AND 40 (BLU WIRE).
3. ☐ CONNECT SPRINGS 14 AND 42 (BLU WIRE).
4. ☐ CONNECT SPRINGS 16 AND 43 (BLU WIRE).
5. ☐ CONNECT SPRINGS 18 AND 45 (BLU WIRE).
6. ☐ CONNECT SPRINGS 41 AND 44 (WHT WIRE).
7. ☐ CONNECT SPRING 41 TO V2 (+3V) (BLU WIRE).
8. ☐ CONNECT SPRINGS 11 AND 13 (WHT WIRE).
9. ☐ CONNECT SPRINGS 13 AND 15 (WHT WIRE).
10. ☐ CONNECT SPRINGS 15 AND 17 (WHT WIRE).
11. ☐ CONNECT SPRING 17 TO GROUND (BLU WIRE).

PUSH THE POWER SWITCH ON. WHEN THE DPDT SWITCH IS DOWN, LEDS 2 AND 4 GLOW. WHEN THE DPDT SWITCH IS UP, LEDS 1 AND 3 GLOW. NOTE THAT DPDT 1 AND DPDT 2 REFER TO THE TWO HALVES OF THE DPDT SWITCH.

8. CONTROL SIX LEDS AT TWO VOLTAGES WITH VARIOUS SWITCHES



MODIFY THE CIRCUIT ABOVE:

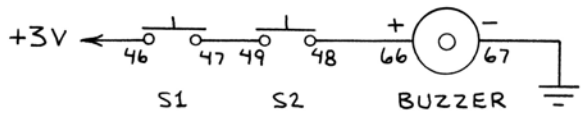
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRINGS 20 AND 47 (BLU WIRE).
3. ☐ CONNECT SPRINGS 22 AND 49 (BLU WIRE).
4. ☐ CONNECT SPRING 46 TO V2 (+3V) (BLU WIRE).
5. ☐ CONNECT SPRING 48 TO V3 (+4.5V) (BLU WIRE).
6. ☐ CONNECT SPRINGS 17 AND 19 (WHT WIRE.)
7. ☐ CONNECT SPRINGS 19 AND 21 (WHT WIRE).

PUSH THE POWER SWITCH ON. WHEN YOU PUSH THE DPDT SWITCH UP AND DOWN, LEDS 1-4 WILL GLOW AS IN THE CIRCUIT ABOVE. AT ANY TIME YOU CAN ALSO ACTIVATE LED 5 BY PRESSING S1. YOU CAN ALSO ACTIVATE LED 6 AT ANY TIME BY PRESSING S2. THE POINT OF ALL THIS IS THAT SIMPLE SWITCH CIRCUITS PROVIDE IMPORTANT FLEXIBILITY IN OUR CIRCUITS.

USING SWITCHES IN SERIES AND PARALLEL

YOU WILL CONNECT TWO OR THREE PUSHBUTTON SWITCHES IN SERIES OR IN PARALLEL. WHILE THESE CIRCUITS ARE VERY SIMPLE, THEY ARE ALSO VERY USEFUL.

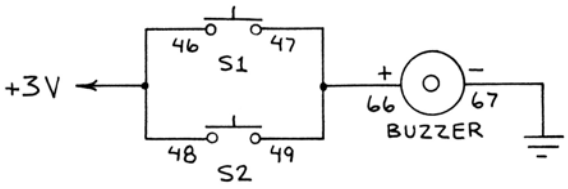
9. CONNECT TWO SWITCHES IN SERIES



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRINGS 48 AND 66 (BLU WIRE).
3. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).
4. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
5. ☐ CONNECT SPRING 46 TO V2 (+3V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS S1 OR S2 AND NOTHING HAPPENS. PRESS S1 AND S2 AND THE BUZZER SOUNDS. LATER YOU WILL LEARN HOW TWO SWITCHES IN SERIES ARE A DECISION MAKING LOGIC CIRCUIT. (THE BUZZER SOUNDS ONLY WHEN BOTH SWITCHES ARE PRESSED.)

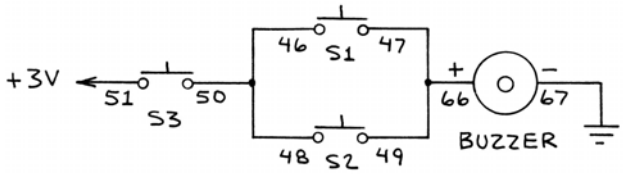
10. CONNECT TWO SWITCHES IN PARALLEL



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRINGS 46 AND 48 (WHT WIRE).
3. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
4. ☐ CONNECT SPRINGS 49 AND 66 (BLU WIRE).
5. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).
6. ☐ CONNECT SPRING 46 TO V2 (+3V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS S1 OR S2 AND THE BUZZER SOUNDS. LATER YOU WILL LEARN HOW TWO SWITCHES IN PARALLEL ARE A DECISION MAKING LOGIC CIRCUIT. (THE BUZZER SOUNDS WHEN EITHER SWITCH IS PRESSED.)

11. CONNECT THREE SWITCHES IN SERIES-PARALLEL

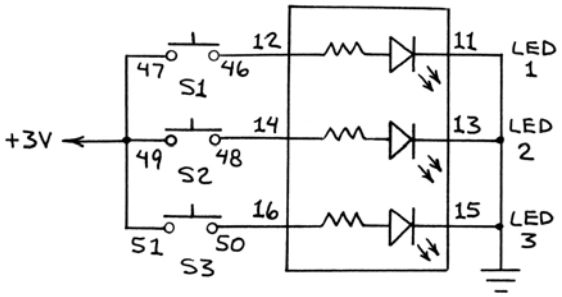


MODIFY THE CIRCUIT ABOVE:

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ MOVE BLU WIRE AT SPRING 46 TO SPRING 51.
3. ☐ CONNECT SPRINGS 48 AND 50 (WHT WIRE).

PUSH THE POWER SWITCH ON. THE BUZZER WILL SOUND ONLY WHEN YOU PRESS S3 AND EITHER S1 OR S2 OR S1 AND S2. THE RESULT IS A DECISION MAKING AND-OR CIRCUIT.

12. USE THREE SWITCHES AS SELECTOR SWITCHES



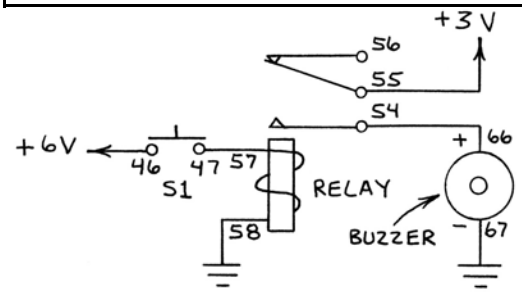
PUSH THE POWER SWITCH ON. PRESS S1, S2 AND/OR S3 TO LIGHT THE RESPECTIVE LEDS.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
3. ☐ CONNECT SPRINGS 49 AND 51 (WHT WIRE).
4. ☐ CONNECT SPRINGS 11 AND 13 (WHT WIRE).
5. ☐ CONNECT SPRINGS 13 AND 15 (WHT WIRE).
6. ☐ CONNECT SPRING 15 TO GROUND (BLU WIRE).
7. ☐ CONNECT SPRINGS 12 AND 46 (BLU WIRE).
8. ☐ CONNECT SPRINGS 14 AND 48 (BLU WIRE).
9. ☐ CONNECT SPRINGS 16 AND 50 (BLU WIRE).
10. ☐ CONNECT SPRING 47 TO V2 (+3V) (BLU WIRE).

THE RELAY AND HOW TO USE IT

THE RELAY IS A SWITCH CONTROLLED BY AN ELECTROMAGNET. HERE'S HOW IT'S USED:

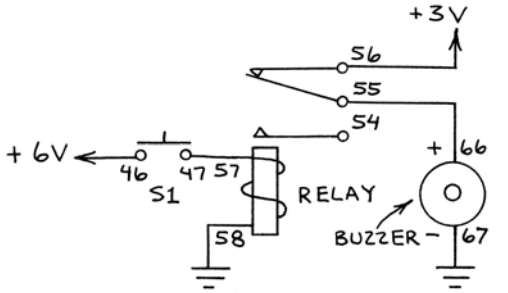
1. USE THE NORMALLY OFF CONTACTS OF THE RELAY TO CONTROL THE BUZZER.



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRING 55 TO V2 (+3V) (BLU WIRE).
3. ☐ CONNECT SPRINGS 54 AND 66 (RED WIRE).
4. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).
5. ☐ CONNECT SPRING 58 TO GROUND (RED WIRE).
6. ☐ CONNECT SPRINGS 47 AND 57 (RED WIRE).
7. ☐ CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS S1, AND THE RELAY WILL PULL IN (HEAR IT CLICK?) AND ACTIVATE THE BUZZER. RELEASE S1, AND THE BUZZER WILL GO SILENT.

2. USE THE NORMALLY ON CONTACTS OF THE RELAY TO CONTROL THE BUZZER

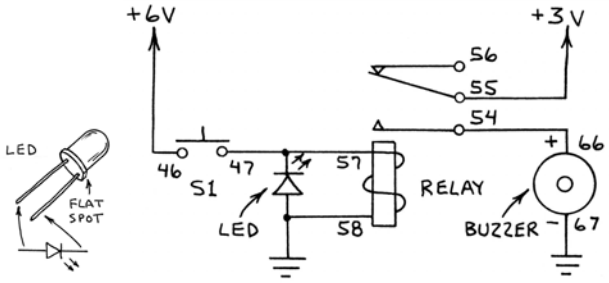


MODIFY THE PREVIOUS CIRCUIT:

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ MOVE BLU WIRE AT SPRING 55 TO SPRING 56.
3. ☐ MOVE RED WIRE AT SPRING 54 TO SPRING 55.

PUSH THE POWER SWITCH ON. THE BUZZER WILL SOUND. PRESS S1, AND THE RELAY WILL PULL IN. THE BUZZER WILL NOW BE SILENT.

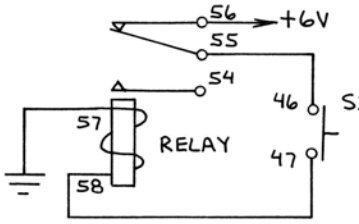
3. USE A DIODE TO PROTECT RELAY DRIVER CIRCUITS



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRINGS 54 AND 66 (BLU WIRE).
3. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).
4. ☐ CONNECT SPRING 58 TO GROUND (RED WIRE).
5. ☐ CONNECT SPRINGS 57 AND 47 (RED WIRE).
6. ☐ CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).
7. ☐ CONNECT SPRING 55 TO V2 (+3V) (BLU WIRE).
8. ☐ INSERT A RED LED ACROSS T25 (CATHODE) AND T26 (ANODE)
9. ☐ CONNECT SPRING 57 TO T23 (RED WIRE).
10. ☐ CONNECT SPRING 58 TO T30 (RED WIRE).

PUSH THE POWER SWITCH ON. PRESS S1, AND THE BUZZER WILL SOUND. RELEASE S1, AND THE BUZZER WILL BE SILENT. AT THE SAME TIME THE LED WILL BRIEFLY FLASH AS THE CURRENT IN THE RELAY COIL COLLAPSES. THE LED ABSORBS THIS CURRENT SPIKE TO PROTECTS EXTERNAL RELAY DRIVER CIRCUITS.

4. USE A RELAY AS AN ELECTROMAGNETIC BUZZER



THE RELAY IS USED AS AN ELECTROMAGNETIC BUZZER.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRINGS 47 AND 58 (BLU WIRE).
3. ☐ CONNECT SPRINGS 46 AND 55 (BLU WIRE).
4. ☐ CONNECT SPRING 57 TO GROUND (RED WIRE).
5. ☐ CONNECT SPRING 56 TO V4 (+6V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS S1 AND THE RELAY WILL HUM. RELAYS ARE NOT DESIGNED TO WORK AS BUZZERS, SO THIS CIRCUIT IS FOR BRIEF DEMONSTRATIONS.

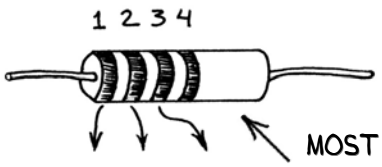
RESISTORS AND HOW TO USE THEM

RESISTORS RESIST THE FLOW OF ELECTRICAL CURRENT. THEY HAVE MANY USES. YOU WILL LEARN HOW TO USE RESISTORS TO REDUCE CURRENT FLOW AND MEASURE VOLTAGE. THE UNIT OF RESISTANCE IS THE OHM. IF A CURRENT OF ONE AMPERE AT A VOLTAGE OF ONE VOLT FLOWS THROUGH A WIRE, THE WIRE HAS A RESISTANCE OF ONE OHM.

THE RESISTOR COLOR CODE

A RESISTOR'S RESISTANCE IS INDICATED BY 4 OR 5 COLORED BANDS OR RINGS:

4 BANDS

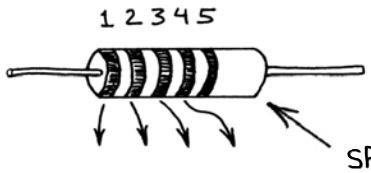


BLACK	0	0	X	1
BROWN	1	1	X	10
RED	2	2	X	100
ORANGE	3	3	X	1,000
YELLOW	4	4	X	10,000
GREEN	5	5	X	100,000
BLUE	6	6	X	1,000,000
VIOLET	7	7	X	10,000,000
GREY	8	8	X	100,000,000
WHITE	9	9		—

THE FOURTH BAND GIVES THE TOLERANCE:
GOLD = +/- 5% SILVER = +/- 10%

EXAMPLE: YELLOW-VIOLET-RED-GOLD IS 47 X 100 OR 4,700 OHMS. GOLD MEANS THE ACTUAL RESISTANCE IS WITHIN 5% OF THIS.

5 BANDS



BLACK	0	0	0	X	1
BROWN	1	1	1	X	10
RED	2	2	2	X	100
ORANGE	3	3	3	X	1,000
YELLOW	4	4	4	X	10,000
GREEN	5	5	5	X	100,000
BLUE	6	6	6	X	1,000,000
VIOLET	7	7	7	X	10,000,000
GREY	8	8	8	X	100,000,000
WHITE	9	9	9		—

THE FIFTH BAND GIVES THE TOLERANCE:
RED = 2%

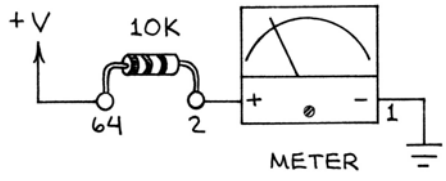
EXAMPLE: RED-BROWN-GREY-BROWN-RED IS 218 X 10 OR 2,180 OHMS. RED MEANS THE ACTUAL RESISTANCE IS WITHIN 2% OF THIS.

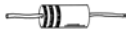
TIP: USE K FOR 1,000 AND M FOR 1,000,000. 4.7K IS 4,700 OHMS. 1M IS 1,000,000 OHMS.

OHM'S LAW AND RESISTANCE

OHM'S LAW LETS YOU FIND THE VOLTAGE (V) ACROSS A RESISTOR, THE CURRENT (I) FLOWING THROUGH IT OR THE RESISTOR'S RESISTANCE (R) IN OHMS IF YOU KNOW TWO OF THESE THREE VALUES. HERE ARE THE FORMULAS: $V = I \times R$ $I = V/R$ $R = V/I$

1. BUILD A CIRCUIT TO MEASURE RESISTANCE





R1-10K
(BRN-BLK-ORG)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT A 10K (10,000 OHM) RESISTOR ACROSS SPRINGS 2 AND 64 (BORROWED).
3. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
4. ☐ CONNECT A YELLOW WIRE TO SPRING 64.

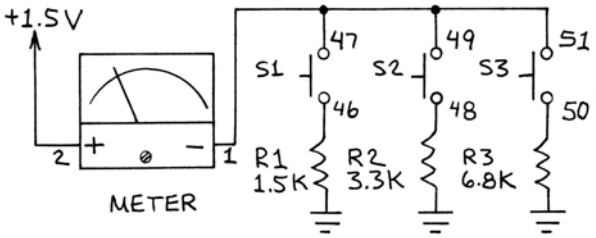
2. TEST THE CIRCUIT

IMPORTANT: BE SURE TO USE A 10K RESISTOR. LESS RESISTANCE MIGHT DAMAGE THE METER. PUSH THE POWER SWITCH ON AND CONNECT THE FREE END OF THE YELLOW WIRE TO V3 (+4.5 VOLTS). THE METER WILL INDICATE ABOUT 0.42 MILLIAMPS (0.00042 AMPS) IF YOUR LEARNING LAB'S BATTERIES ARE FRESH. FROM OHM'S LAW, THE RESISTANCE IS 10,714 OHMS (4.5 VOLTS/0.00042 AMPS). THIS IS WITHIN 7% OF SPECIFIED RESISTANCE. WHAT IS YOUR RESULT?

OHM'S LAW AND CURRENT

CURRENT IS MEASURED IN AMPERES. OHM'S LAW SHOWS THAT THE CURRENT (I) THROUGH A CIRCUIT EQUALS THE VOLTAGE (V) ACROSS THE CIRCUIT DIVIDED BY THE CIRCUIT'S RESISTANCE (R) IN OHMS OR I = V/R. SOME PARTS, LIKE LIGHT-EMITTING DIODES (LEDS), ARE DAMAGED BY EXCESSIVE CURRENT. RESISTORS ARE USED TO LIMIT (REDUCE) CURRENT.

1. BUILD A CIRCUIT THAT SHOWS HOW RESISTANCE REDUCES CURRENT



R1-1.5K (1500 OHMS) (BRN-GRN-RED)
R2-3.3K (3300 OHMS) (ORG-ORG-RED)
R3-6.8K (6800 OHMS) (BLU-GRY-RED)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSTALL R1 ACROSS SPRING 46 AND GROUND.
3. ☐ INSTALL R2 ACROSS SPRING 48 AND GROUND.
4. ☐ INSTALL R3 ACROSS SPRING 50 AND GROUND.
5. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
6. ☐ CONNECT SPRINGS 49 AND 51 (WHT WIRE).
7. ☐ CONNECT SPRINGS 51 AND 1 (BLU WIRE).
8. ☐ CONNECT SPRING 2 TO V1 (+1.5V) (YEL WIRE).

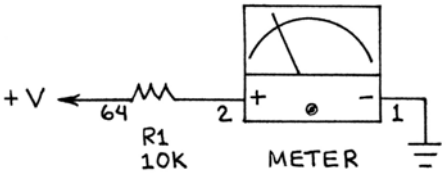
2. TEST THE CIRCUIT

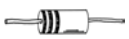
IMPORTANT: BE SURE THAT NO RESISTOR IS LESS THAN 1.5K. TOO LITTLE RESISTANCE MIGHT DAMAGE THE METER. PUSH THE POWER SWITCH ON AND PRESS S1 TO CONNECT THE SMALLEST RESISTOR BETWEEN THE POWER SUPPLY AND THE METER. THE METER WILL INDICATE ABOUT 0.88 MA. PRESS S2 AND THE METER WILL INDICATE ABOUT 0.42 MA. PRESS S3 AND THE METER WILL INDICATE ABOUT 0.19 MA. NOTICE HOW THE CURRENT FALLS WHEN RESISTANCE RISES.

OHM'S LAW AND VOLTAGE

VOLTAGE IS MEASURED IN VOLTS. OHM'S LAW SHOWS THAT THE VOLTAGE (V) ACROSS A CIRCUIT EQUALS THE CIRCUIT'S RESISTANCE (R) TIMES THE CURRENT (I) THROUGH THE CIRCUIT OR V = I X R. THE CURRENT METER ON YOUR LEARNING LAB CAN BE USED TO MEASURE 0 TO 10 VOLTS IF YOU CONNECT A 10,000 OHM RESISTOR IN SERIES WITH IT.

1. BUILD A VOLTMETER, A CIRCUIT THAT MEASURES VOLTAGE





R1-10K
(BLK-BRN-ORG)

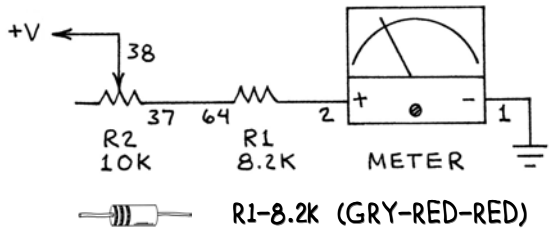
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS SPRINGS 64 AND 2.
3. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
4. ☐ CONNECT A YELLOW WIRE TO SPRING 64.

2. TEST THE VOLTMETER

MAKE SURE THAT R1 IS A 10K RESISTOR. THEN PUSH THE POWER SWITCH ON. IMAGINE THAT THE NUMBERS ON THE METER'S SCALE HAVE NO DECIMAL POINTS, AND THAT THEY INDICATE 0 TO 10 VOLTS. NOW CONNECT THE FREE END OF THE YELLOW "PROBE" WIRE TO +1.5V. THE METER WILL INDICATE ABOUT 1.4 VOLTS. THE TABLE SHOWS THE VOLTAGES MEASURED WITH A LEARNING LAB WITH FRESH BATTERIES. THE ERROR BETWEEN THE REAL VOLTAGE AND THAT INDICATED BY THE METER IS AROUND 6-7%. IN THE NEXT PROJECT YOU WILL REDUCE THIS ERROR.

ACTUAL-VOLTAGE	METER VOLTAGE
1.5 (V1)	1.4
3.0 (V2)	2.8
4.5 (V3)	4.2
6.0 (V4)	5.8
7.5 (V5)	7.0
9.0 (V6)	8.5

3. BUILD A BETTER VOLTMETER



R1-8.2K (GRY-RED-RED)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS SPRINGS 64 AND 2.
3. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
4. ☐ CONNECT SPRINGS 64 AND 37 (YEL WIRE).
5. ☐ CONNECT A YELLOW WIRE TO SPRING 38. (NOTE THAT R2 IS A POTENTIOMETER.)

4. TEST THE BETTER VOLTMETER

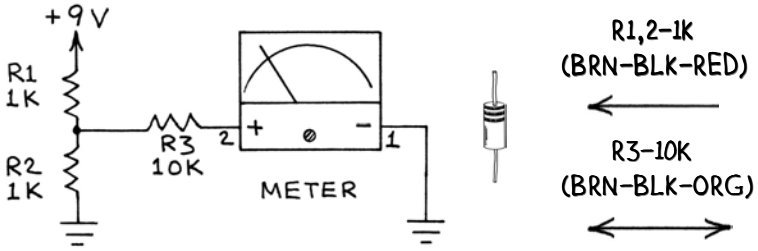
MAKE SURE THAT R1 IS AN 8.2K RESISTOR. THEN PUSH THE POWER SWITCH ON. AGAIN, IMAGINE THAT THE NUMBERS ON THE METER'S SCALE HAVE NO DECIMAL POINTS, AND THAT THEY INDICATE 0 TO 10 VOLTS. CONNECT THE FREE END OF THE YELLOW "PROBE" WIRE TO +6V (V4). THEN ADJUST CONSOLE POTENTIOMETER R2 UNTIL THE METER NEEDLES POINTS TO EXACTLY 6 VOLTS (0.6 MA). NOW CONNECT THE PROBE WIRE TO EACH +V POINT (V1-V6) WHILE WATCHING THE METER. THE TABLE SHOWS THE VOLTAGES MEASURED WITH A LEARNING LAB WITH FRESH BATTERIES. THE ACCURACY IS WITHIN 0.1 VOLT. DIGITAL VOLTMETERS GIVE MUCH BETTER RESULTS.

ACTUAL-VOLTAGE	METER VOLTAGE
1.5 (V1)	1.4
3.0 (V2)	2.9
4.5 (V3)	4.4
6.0 (V4)	6.0
7.5 (V5)	7.4
9.0 (V6)	9.0

USE RESISTORS TO DIVIDE VOLTAGE

VOLTAGE DIVIDERS PROVIDE CUSTOM VOLTAGES IN CIRCUITS. THE FORMULA IS: VOLTAGE OUT (V_{OUT}) = VOLTAGE IN (V_{IN}) X R2/(R1 + R2). THE CIRCUITS BELOW USE YOUR LEARNING LAB METER AS A VOLTMETER.

1. BUILD A FIXED VOLTAGE DIVIDER



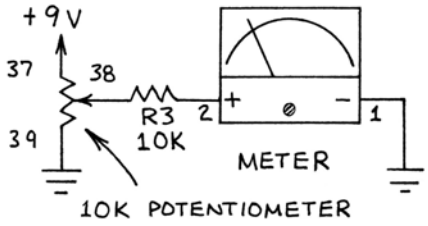
R1,2-1K
(BRN-BLK-RED)

R3-10K
(BRN-BLK-ORG)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS L26 AND V6 (+9V).
3. ☐ INSERT R2 ACROSS L27 AND GROUND.
4. ☐ INSERT R3 ACROSS SPRINGS 2 AND 64.
5. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
6. ☐ CONNECT A YELLOW WIRE TO SPRING 64.

PUSH THE POWER SWITCH ON. TOUCH THE YELLOW "PROBE" WIRE TO +9V. THE METER WILL INDICATE ABOUT 8.4 VOLTS (0.84 MA). TOUCH THE PROBE TO THE JUNCTION OF R1 AND R2 AND THE METER VOLTAGE WILL BE HALVED. THIS FITS THE FORMULA, WHICH SHOWS THAT WHEN R1 = R2, THE OUTPUT VOLTAGE WILL BE 1/2 THE INPUT VOLTAGE (1000/(1000+1000) = 0.5.

2. BUILD AN ADJUSTABLE VOLTAGE DIVIDER



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R3 ACROSS SPRINGS 2 AND 64.
3. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
4. ☐ CONNECT SPRINGS 38 AND 64 (YEL WIRE).
5. ☐ CONNECT SPRING 37 TO V6 (+9V) (BLU WIRE).
6. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).

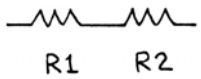
PUSH THE POWER SWITCH ON AND ROTATE THE POTENTIOMETER KNOB WHILE WATCHING THE METER. NOTE THAT THE METER VOLTAGE IS HIGHEST WHEN THE KNOB IS ROTATED TOWARD SPRING 37, WHICH GOES TO +9 VOLTS.

A VOLTAGE DIVIDER BRAIN TEASER

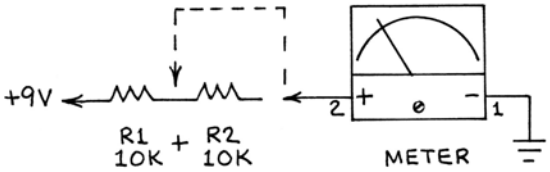
IF V_{IN} = 9 VOLTS AND R2 = 10K, WHAT RESISTANCE IS R1 FOR V_{OUT} = 6 VOLTS? (ANSWER: 5K.)

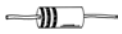
CONNECT RESISTORS IN SERIES TO INCREASE RESISTANCE AND REDUCE CURRENT FLOW

THE TOTAL RESISTANCE OF TWO RESISTORS CONNECTED IN SERIES IS THE SUM OF THE INDIVIDUAL RESISTANCES. THE FORMULA IS: TOTAL R = R1 + R2.



1. BUILD A CIRCUIT TO TEST TWO RESISTORS IN SERIES



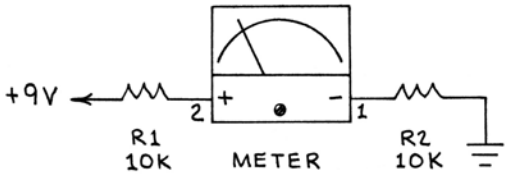


R1,2-10K (BRN-BLK-ORG)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS V6 (+9V) AND J26.
3. ☐ INSERT R2 ACROSS J28 AND T28.
4. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
5. ☐ CONNECT A YELLOW WIRE TO SPRING 2.

PUSH THE POWER SWITCH ON AND TOUCH THE FREE END OF THE YELLOW WIRE TO THE JUNCTION OF R1 AND R2. THE METER WILL INDICATE ABOUT 0.84 MA. NOW MOVE THE YELLOW WIRE TO THE FREE END OF R2 (AT T30). THE METER WILL INDICATE ABOUT 0.42 MA. SINCE THE CURRENT IS HALVED, THIS TEST PROVES THAT RESISTANCE IS DOUBLED WHEN TWO RESISTORS OF THE SAME VALUE ARE CONNECTED IN SERIES. (EXACT CURRENT DEPENDS ON THE VOLTAGE OF THE BATTERIES IN YOUR LEARNING LAB.)

2. REARRANGE THE RESISTORS IN THE SERIES CIRCUIT

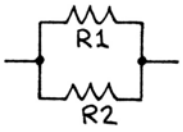


1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS J26 AND V6 (+9V).
3. ☐ INSERT R2 ACROSS M26 AND GROUND.
4. ☐ CONNECT SPRING 1 TO M30 (BLU WIRE).
5. ☐ CONNECT SPRING 2 TO J30 (YEL WIRE).

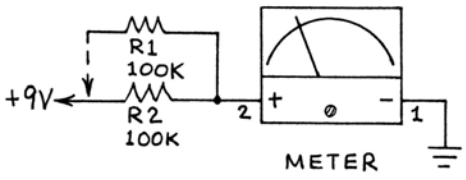
PUSH THE POWER SWITCH ON. THE METER WILL INDICATE ABOUT 0.42 MA, THE SAME CURRENT IN THE PREVIOUS PROJECT. THIS PROVES THAT THE CURRENT FLOWING THROUGH A SERIES CIRCUIT REMAINS THE SAME EVEN WHEN THE RESISTORS ARE REARRANGED.

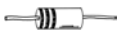
CONNECT RESISTORS IN PARALLEL TO REDUCE RESISTANCE AND INCREASE CURRENT FLOW

THE TOTAL RESISTANCE OF TWO RESISTORS CONNECTED IN PARALLEL IS THE PRODUCT OF THE TWO RESISTANCES DIVIDED BY THEIR SUM. THE FORMULA IS: TOTAL R = (R1 X R2)/(R1 + R2).



1. BUILD A CIRCUIT TO TEST TWO RESISTORS IN PARALLEL





R1,2-100K (BRN-BLK-YEL)

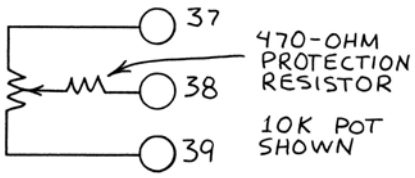
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R2 ACROSS V6 (+9V) AND J26.
3. ☐ INSERT ONE LEAD OF R1 INTO J28. LEAVE THE OTHER LEAD DISCONNECTED.
4. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
5. ☐ CONNECT SPRING 2 TO J30 (YEL WIRE).

PUSH THE POWER SWITCH ON. THE METER WILL INDICATE ABOUT 0.08 MA. INSERT THE FREE LEAD OF R1 INTO A V6 (+9V) BREADBOARD HOLE. THE METER WILL INDICATE ABOUT 0.16 MA. SINCE THE CURRENT IS DOUBLED, THIS PROVES THAT RESISTANCE IS HALVED WHEN TWO RESISTORS OF THE SAME VALUE ARE CONNECTED IN PARALLEL. REPLACE R1 WITH A 47K RESISTOR (YEL-VIO-ORG). WHAT DOES THE METER INDICATE? (ANSWER: ABOUT 0.24 MA.) USE THE FORMULA TO FIND THE TOTAL R. (ANSWER: 32K.) YOUR RESULTS WILL DEPEND ON THE VOLTAGE OF THE BATTERIES IN YOUR LEARNING LAB.

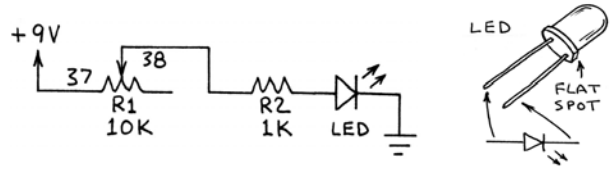
THE CONSOLE POTENTIOMETERS AND HOW TO USE THEM

A POTENTIOMETER ("POT") IS AN ADJUSTABLE (VARIABLE) RESISTOR. THREE POTENTIOMETERS ARE INSTALLED ON THE CONSOLE OF YOUR LEARNING LAB. YOU WILL USE THESE POTS TO ADJUST THE VOLUME OF SOUND FROM THE SPEAKER AND EARPHONE AND TO CHANGE THE TIME DELAY OF TIMERS AND THE FREQUENCY OF OSCILLATORS. YOU WILL ALSO USE THE POTS AS VOLTAGE DIVIDERS AND TO CONTROL THE CURRENT SUPPLIED TO LEDS AND THE METER.

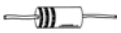
ALL THREE POTS HAVE A 470-OHM RESISTOR BETWEEN THE ROTATING TERMINAL (WIPER OR ROTOR) AND THE CONSOLE SPRING TO PROTECT THE POT FROM EXCESSIVE CURRENT. THE PROTECTION RESISTORS ARE NOT SHOWN IN THE CIRCUIT DIAGRAMS. BE SURE TO INCLUDE THIS RESISTOR IF YOU BUILD PERMANENT VERSIONS OF CIRCUITS THAT USE POTS IN YOUR LEARNING LAB MANUALS.



1. BUILD AN LED BRIGHTNESS CONTROL



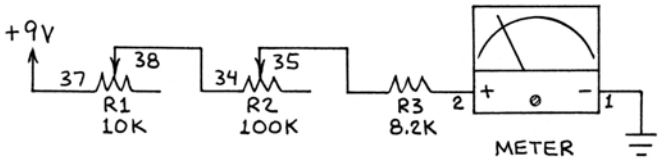
CHECK FOR ERRORS AND PUSH THE POWER SWITCH ON. ADJUST R1, THE 10K CONSOLE POTENTIOMETER, TO CONTROL THE BRIGHTNESS OF THE LED.



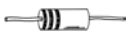
R2-1K (BRN-BLK-RED)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSTALL R2 ACROSS M28 AND T28.
3. ☐ INSTALL THE LED ACROSS T26 (ANODE) AND GROUND (CATHODE).
4. ☐ CONNECT SPRING 38 TO M26 (BLU WIRE).
5. ☐ CONNECT SPRING 37 TO TO V6 (+9V) (BLU WIRE).

2. BUILD A DEMONSTRATION ANALOG COMPUTER ADDER



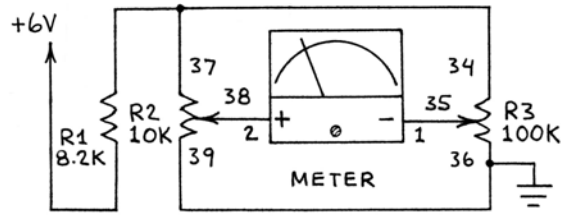
CHECK FOR ERRORS. PUSH THE POWER SWITCH ON. THE RESISTANCE OF TWO RESISTORS IN SERIES IS THEIR SUM. THUS THE METER READING IS PROPORTIONAL TO R1 + R2. A PRACTICAL ADDER REQUIRES CALIBRATION DIALS.



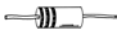
R3-8.2K (GRY-RED-RED)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSTALL R3 ACROSS SPRINGS 2 AND 64.
3. ☐ CONNECT SPRINGS 38 AND 34 (RED WIRE).
4. ☐ CONNECT SPRINGS 35 AND 64 (YEL WIRE).
5. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
6. ☐ CONNECT SPRING 37 TO V6 (+9V) (BLU WIRE).

3. BUILD A WHEATSTONE BRIDGE (NAMED FOR SIR CHARLES WHEATSTONE)



ROTATE THE 10K AND 100K POTS (R2 AND R3) LEFT. PUSH POWER SWITCH ON. ADJUST R2 FIRST, THEN R3, TO AVOID REVERSE CURRENT THROUGH THE METER. WHEN R2 AND R3 ARE SET TO GIVE THE SAME VOLTAGE, THE BRIDGE IS BALANCED AND THE METER READS 0. OTHERWISE THE BRIDGE IS UNBALANCED.



R1-8.2K (GRY-RED-RED)

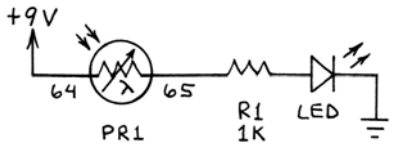
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS V4 (+6V) AND B21.
3. ☐ CONNECT SPRINGS 36 AND 39 (RED WIRE.)
4. ☐ CONNECT SPRINGS 37 AND 34 (RED WIRE).
5. ☐ CONNECT SPRINGS 2 AND 38 (YEL WIRE).
6. ☐ CONNECT SPRINGS 1 AND 35 (YEL WIRE).
7. ☐ CONNECT SPRING 36 TO GROUND (RED WIRE).
8. ☐ CONNECT SPRING 37 TO B25 (BLU WIRE).

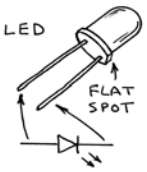
DO NOT ALLOW THE METER NEEDLE TO MOVE BELOW 0 WHILE ADJUSTING POTS R2 AND R3.

THE PHOTORESISTOR AND HOW TO USE IT

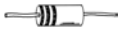
A LIGHT-SENSITIVE PHOTORESISTOR IS INSTALLED ON THE CONSOLE OF YOUR LEARNING LAB. IT HAS MANY NEAT APPLICATIONS, INCLUDING THOSE SHOWN HERE.

1. BUILD A LIGHT-ACTIVATED LIGHT USING A PHOTORESISTOR



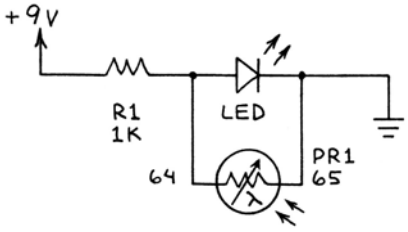


CHECK FOR ERRORS AND THEN PUSH THE POWER SWITCH ON. SHINE A FLASHLIGHT ON THE PHOTORESISTOR AND THE LED WILL GLOW.

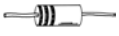

RED LED

R1-1K (BRN-BLK-RED)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS M28 AND T28.
3. ☐ INSERT LED ACROSS T26 (ANODE) AND GROUND (CATHODE).
4. ☐ CONNECT SPRING 64 TO V6 (+9V) (BLU WIRE).
5. ☐ CONNECT SPRING 65 TO M30 (BLU WIRE).

2. BUILD A DARK-ACTIVATED LIGHT USING A PHOTORESISTOR

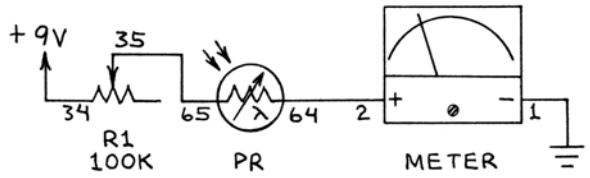


CHECK FOR ERRORS AND PUSH THE POWER SWITCH ON. THE LED WILL GLOW. SHINE LIGHT ON THE PHOTORESISTOR, AND THE LED WILL TURN OFF.


RED LED

R1-1K (BRN-BLK-RED)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS M28 AND T28.
3. ☐ INSERT LED ACROSS T26 (ANODE) AND GROUND (CATHODE).
4. ☐ CONNECT M30 TO V6 (+9V) (RED WIRE).
5. ☐ CONNECT SPRING 64 TO T30 (BLU WIRE).
6. ☐ CONNECT SPRING 65 TO GROUND (BLU WIRE).

3. BUILD A LIGHT METER USING A PHOTORESISTOR

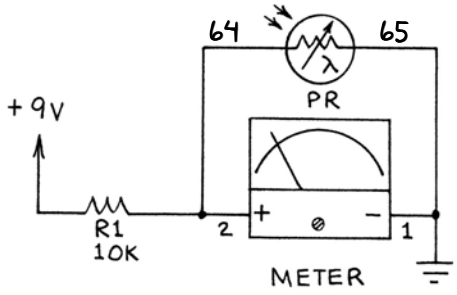


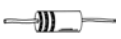
R1 IS THE 100K CONSOLE POTENTIOMETER.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
3. ☐ CONNECT SPRINGS 2 AND 64 (WHT WIRE).
4. ☐ CONNECT SPRINGS 35 AND 65 (YEL WIRE).
5. ☐ CONNECT SPRING 34 TO V6 (+9V) (BLU WIRE).

PUSH THE POWER SWITCH ON. BLOCK THE PHOTORESISTOR WITH A FINGER AND ADJUST R1 FOR THE LOWEST CURRENT READING. THE METER NEEDLE WILL MOVE UP IN RESPONSE TO LIGHT.

4. BUILD A DARK METER USING A PHOTORESISTOR




R1-10K
(BRN-BLK-ORG)

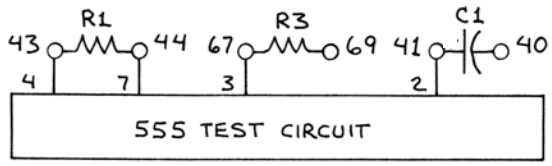
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS V6 (+9V) AND J26.
3. ☐ CONNECT SPRING 2 TO J30 (BLU WIRE).
4. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
5. ☐ CONNECT SPRINGS 1 AND 65 (WHT WIRE.)
6. ☐ CONNECT SPRINGS 2 AND 64 (WHT WIRE).

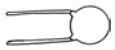
PUSH THE POWER SWITCH ON. THE METER WILL INDICATE A CURRENT. LIGHT WILL REDUCE THE CURRENT SLIGHTLY.

APPLY WHAT YOU'VE LEARNED: RESISTORS AND THE 555 "BLACK BOX" TEST CIRCUIT

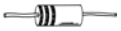
YOU WILL USE RESISTORS TO CONTROL THE TONE FROM THE "BLACK BOX" TEST CIRCUIT ON PAGE 19. THE DIAGRAMS SHOW ONLY CHANGES MADE TO THE BLACK BOX TEST CIRCUIT, SO BE SURE TO BUILD EACH CIRCUIT IN ORDER. AND GET READY FOR SOME FUN!

1. PREPARE THE BLACK BOX CIRCUIT AND SET THE TONE FREQUENCY WITH A RESISTOR





C1-0.1 UF (104)



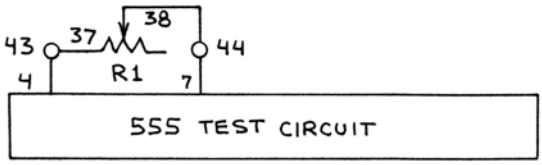
R1-10K (BRN-BLK-ORG)
R3-470 (YEL-VIO-BRN)

BE SURE THE 555 TEST CIRCUIT IS CONNECTED PROPERLY AND THE DPDT SWITCH IS PUSHED DOWN. THEN PUSH THE POWER SWITCH ON. THE SPEAKER WILL EMIT A FIXED TONE AT A FREQUENCY OF ABOUT 1,000 HZ.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS SPRINGS 43 AND 44.
3. ☐ INSERT R3 ACROSS SPRINGS 67 AND 69.
4. ☐ INSERT C1 ACROSS SPRINGS 40 AND 41.

(BE SURE THE 555 IS CONNECTED TO +6V WITH A WHITE WIRE FROM F20 TO V4.)

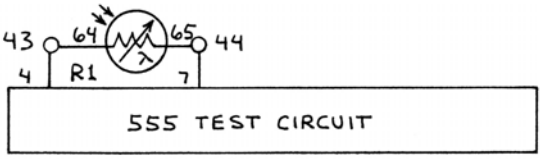
2. USE A POTENTIOMETER TO CHANGE THE TEST CIRCUIT'S TONE FREQUENCY



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE R1 FROM SPRINGS 43 AND 44.
3. ☐ CONNECT SPRINGS 37 AND 43 (RED WIRE).
4. ☐ CONNECT SPRINGS 38 AND 44 (RED WIRE).

PUSH THE POWER SWITCH ON. THE SPEAKER WILL EMIT A TONE. ROTATE 10K POTENTIOMETER R1 WHILE LISTENING TO THE TONE. THE TONE WILL CHANGE FROM ABOUT 1,000 HZ TO ABOUT 4,800 HZ BEFORE CUTTING OFF. THE FREQUENCY INCREASES AS THE RESISTANCE OF R1 FALLS.

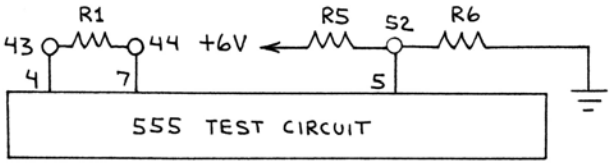
3. USE A PHOTORESISTOR TO CHANGE THE TONE FREQUENCY WITH LIGHT

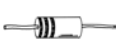


1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ DISCONNECT 10K POT FROM SPRINGS 43 AND 44.
3. ☐ CONNECT SPRINGS 64 AND 43 (BLU WIRE).
4. ☐ CONNECT SPRINGS 65 AND 44 (BLU WIRE).

PUSH THE POWER SWITCH ON. THE SPEAKER WILL EMIT A TONE. PLACE YOUR FINGER OVER THE PHOTORESISTOR AND THE TONE WILL CHANGE TO A SLOW BUZZ. ILLUMINATE THE PHOTORESISTOR WITH A FLASHLIGHT OR SUNLIGHT AND THE BUZZ WILL BECOME A VERY HIGH-PITCHED TONE. TOO MUCH LIGHT WILL STOP THE TONE.

4. USE A FIXED RESISTOR VOLTAGE DIVIDER TO SET THE TONE FREQUENCY



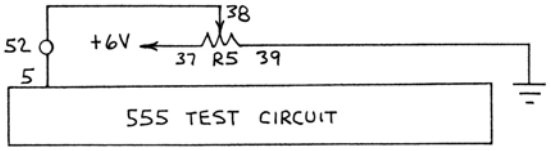


R1, R5, R6-10K (BRN-BLK-ORG)

PUSH THE POWER SWITCH ON. THE VOLTAGE DIVIDER (R5 AND R6) PROVIDES A VOLTAGE AT PIN 5 OF THE 555, WHICH SETS THE TONE FREQUENCY. REMOVE THE RED WIRE FROM SPRING 52 AND THE FREQUENCY WILL FALL.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ DISCONNECT THE PHOTORESISTOR FROM SPRINGS 43 AND 44.
3. ☐ INSERT R1 ACROSS SPRINGS 43 AND 44.
4. ☐ INSERT R5 ACROSS SPRING 52 AND T30.
5. ☐ INSERT R6 ACROSS SPRING 52 AND GROUND.
6. ☐ CONNECT T28 TO V4 (+6V) (RED WIRE).

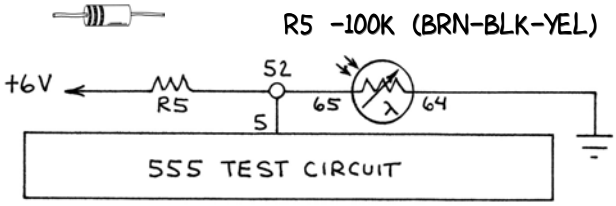
5. USE AN ADJUSTABLE VOLTAGE DIVIDER TO CHANGE THE TONE FREQUENCY



PUSH THE POWER SWITCH ON. ADJUST THE 10K CONSOLE POTENTIOMETER, R5, TO VARY THE FREQUENCY OF THE TONE.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE OLD R5 AND R6 FROM SPRING 52.
3. ☐ REMOVE RED WIRE ACROSS T28 AND V4.
4. ☐ CONNECT SPRING 37 TO V4 (+6V) (BLU WIRE).
5. ☐ CONNECT SPRINGS 38 AND 52 (BLU WIRE).
6. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).

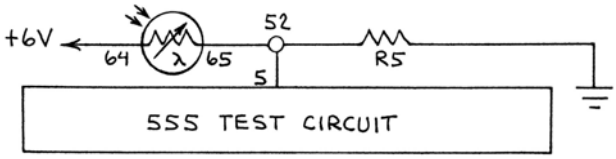
6. USE A LIGHT-SENSITIVE VOLTAGE DIVIDER TO INCREASE THE TONE FREQUENCY



PUSH THE POWER SWITCH ON. LIGHT AT THE PHOTORESISTOR WILL INCREASE THE FREQUENCY OF THE TONE.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE THE THREE BLUE WIRES BETWEEN SPRINGS 37, 38 AND 39 AND V4, SPRING 52 AND GROUND.
3. ☐ INSERT R5 ACROSS SPRING 52 AND T30.
4. ☐ CONNECT T26 TO V4 (+6V) (RED WIRE).
5. ☐ CONNECT SPRINGS 52 AND 65 (BLU WIRE).
6. ☐ CONNECT SPRING 64 TO GROUND (BLU WIRE).

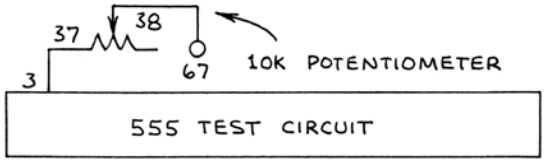
7. USE A LIGHT-SENSITIVE VOLTAGE DIVIDER TO REDUCE THE TONE FREQUENCY



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ MOVE R5 LEAD AT T30 TO GROUND.
3. ☐ MOVE BLUE WIRE LEADING FROM SPRING 64 FROM GROUND TO T30.

PUSH THE POWER SWITCH ON. LIGHT AT THE PHOTORESISTOR WILL REDUCE THE FREQUENCY OF THE TONE. TRY EXPERIMENTING WITH VARIOUS VALUES OF R5 FOR DIFFERENT EFFECTS.

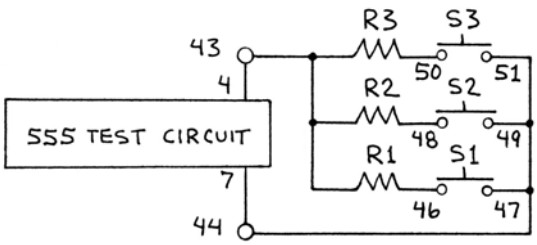
8. USE A POTENTIOMETER TO CONTROL THE TONE VOLUME



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE BLUE WIRES AT SPRINGS 64 AND 65.
3. ☐ MOVE BLUE WIRE AT SPRING 67 TO SPRING 37.
4. ☐ CONNECT SPRINGS 67 AND 38 (YEL WIRE).

PUSH THE POWER SWITCH ON. ADJUST THE 10K CONSOLE POTENTIOMETER TO CHANGE THE VOLUME (LOUDNESS) OF THE TONE. OK TO USE THIS VOLUME CONTROL WITH ANY 555 CIRCUIT.

9. USE RESISTORS AND A "KEYBOARD" TO CONTROL THE TONE FREQUENCY



PUSH THE POWER SWITCH ON. PRESS S1, S2 AND/OR S3 TO GENERATE VARIOUS TONES. CHANGE RESISTORS FOR DIFFERENT TONES.

R1,2,3-USE ANY RESISTORS OVER 10K

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS SPRING 46 AND T22.
3. ☐ INSERT R2 ACROSS SPRING 48 AND T23.
4. ☐ INSERT R3 ACROSS SPRING 50 AND T24.
5. ☐ CONNECT SPRINGS 44 AND 47 (WHT WIRE).
6. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
7. ☐ CONNECT SPRINGS 49 AND 51 (WHT WIRE).
8. ☐ CONNECT SPRING 43 AND T21 (RED WIRE).

CAPACITORS AND HOW TO USE THEM

CAPACITORS BLOCK THE FLOW OF DIRECT (CONTINUOUS) ELECTRICAL CURRENT WHILE PASSING ALTERNATING (FLUCTUATING) CURRENT OR PULSES OF CURRENT. CAPACITORS CAN ALSO STORE AN ELECTRICAL CHARGE AND SMOOTH A FLUCTUATING CURRENT. THESE CAPABILITIES GIVE CAPACITORS MANY IMPORTANT APPLICATIONS IN ELECTRONIC CIRCUITS. THE UNIT OF CAPACITANCE IS THE FARAD (F)

CAPACITORS SUPPLIED WITH YOUR LEARNING LAB

A CAPACITOR CONSISTS OF TWO CONDUCTING PLATES SEPARATED BY AN INSULATOR CALLED THE DIELECTRIC. THE MOST IMPORTANT CAPACITORS ARE CERAMIC AND ELECTROLYTIC, AND YOUR LEARNING LAB IS SUPPLIED WITH BOTH KINDS.

CERAMIC DISK CAPACITORS

CERAMIC CAPACITORS ARE MADE BY COATING A CERAMIC DIELECTRIC WITH METAL. THE CAPACITOR IS PROTECTED WITH A COATING OF INSULATION. TYPICAL CAPACITANCE RANGES FROM 10 PICOFARADS TO 0.47 MICROFARAD. SMALL CAPACITY CERAMIC CAPACITORS ARE SMALLER IN SIZE THAN LARGE VALUE UNITS RATED FOR THE SAME OPERATING VOLTAGE.

ELECTROLYTIC CAPACITORS

ELECTROLYTIC CAPACITORS ARE MADE BY ROLLING TWO STRIPS OF METAL FOIL INTO A CYLINDER. THE FOIL STRIPS ARE SEPARATED BY A DIELECTIC OF PAPER SOAKED IN AN ELECTROLYTE (AN ELECTRICALLY CONDUCTIVE LIQUID OR PASTE). ELECTROLYTIC CAPACITORS ARE POLARIZED. THIS MEANS THAT ONE LEAD MUST ALWAYS BE AT A HIGHER POTENTIAL (VOLTAGE) THAN THE OTHER. REVERSING THE CONNECTION MAY DAMAGE THE CAPACITOR. THE POSITIVE (+) OR MINUS (-) LEAD OF A POLARIZED CAPACITOR IS ALWAYS MARKED ON THE CASE. ELECTROLYTIC CAPACITORS HAVE MUCH HIGHER CAPACITANCE THAN CERAMIC CAPACITORS. THEY ARE OFTEN LARGER THAN CERAMIC CAPACITORS.

HOW CAPACITORS ARE IDENTIFIED AND RATED

MOST CAPACITORS HAVE A CAPACITANCE OF ONLY A FEW MILLIONTHS OF A FARAD. THE RANGE IS SO GREAT THAT CAPACITORS ARE SPECIFIED ACCORDING TO MILLIONTHS (MICROFARAD OR UF) OR TRILLIONTHS (PICOFARAD OR PF) OF A FARAD. THE TABLE SHOWS THE RELATIONSHIP OF FARADS, MICROFARADS AND PICOFARADS.

ELECTROLYTIC CAPACITORS ARE USUALLY LARGE ENOUGH FOR THE VALUE IN UF TO BE MARKED ON THEIR CASE. CERAMIC DISK CAPACITORS CAN BE MARKED WITH THE VALUE IN UF (LIKE 0.1 FOR 0.1 MICROFARD) OR WITH A 3-DIGIT CODE THAT GIVES THE CAPACITANCE IN PICOFARADS. THE FIRST TWO DIGITS GIVE THE VALUE AND THE LAST DIGIT GIVES THE NUMBER OF ZEROES. NO LAST DIGIT MEANS NO ZEROES. EXAMPLE: 104 MEANS 10 FOLLOWED BY 4 ZEROES OR A CAPACITANCE OF 100,000 PF. FROM THE TABLE, THIS IS THE SAME AS 0.1 UF.

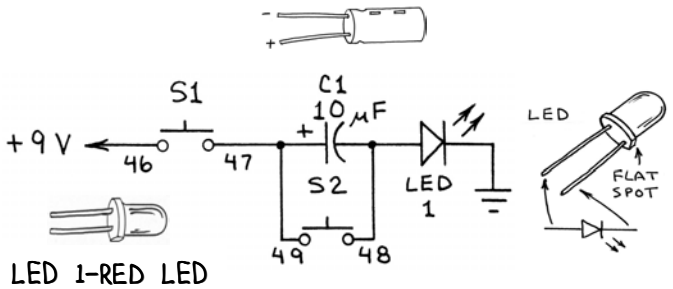
FARADS (F)	MICROFARADS (UF)	PICOFARADS (PF)
0.001	1,000	1,000,000,000
0.0001	100	100,000,000
0.00001	10	10,000,000
0.000001	1	1,000,000
0.0000001	0.1	100,000
0.00000001	0.01	10,000
0.000000001	0.001	1,000

MICROFARAD = PICOFARAD/1,000,000
EXAMPLE: WHAT IS THE VALUE IN UF OF A DISK CAPACITOR MARKED 103? THE VALUE IN PF IS 10 + 000 OR 10,000 PF. 10,000/1,000,000 = 0.01. THE CAPACITOR HAS A VALUE OF 0.01 UF.

CAPACITORS VERSUS DIRECT CURRENT AND FLUCTUATING CURRENT

THE BEST WAY TO LEARN ABOUT CAPACITORS IS TO USE THEM IN SOME SIMPLE CIRCUITS. THE CIRCUITS ON THIS PAGE SHOW HOW CAPACITORS PASS PULSES OF CURRENT, BLOCK CONTINUOUS CURRENT AND STORE AN ELECTRICAL CHARGE.

1. BUILD A CIRCUIT THAT PASSES PULSES OF CURRENT BUT BLOCKS A STEADY CURRENT

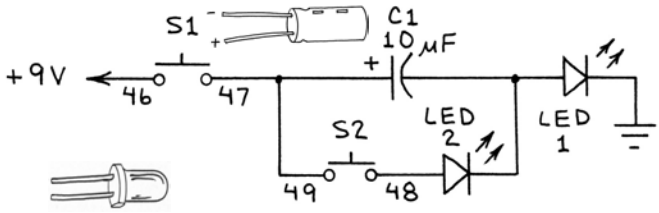


LED 1-RED LED

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T25 (+) AND T26 (-).
3. ☐ INSERT LED 1 ACROSS T28 (ANODE) AND GROUND (CATHODE).
4. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
5. ☐ CONNECT SPRING 48 TO T30 (RED WIRE).
6. ☐ CONNECT SPRING 49 TO T21 (RED WIRE).
7. ☐ CONNECT SPRING 46 TO V6 (+9V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS S1, AND THE LED WILL FLASH. THIS SHOWS THAT C1 PASSES THE INITIAL PULSE OF CURRENT WHEN S1 IS CLOSED. AFTER THE INITIAL PULSE, THE LED WILL STAY OFF, EVEN WHEN S1 IS CLOSED. THIS SHOWS THAT C1 BLOCKS DIRECT CURRENT. TO REPEAT, BRIEFLY PRESS S2 TO DISCHARGE THE CAPACITOR. THEN PRESS S1 AGAIN.

2. BUILD A CIRCUIT THAT SHOWS HOW A CAPACITOR STORES ENERGY



LED 1-RED LED
LED 2-GREEN LED

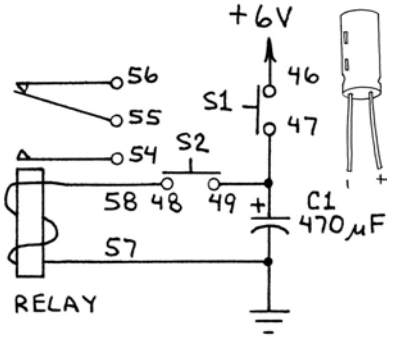
CAUTION: DO NOT PRESS S1 AND S2 AT THE SAME TIME!

MODIFY THE ADJACENT CIRCUIT BY FOLLOWING THESE STEPS:

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT LED 2 ACROSS R29 (ANODE) AND T29 (CATHODE).
3. ☐ MOVE THE RED WIRE BETWEEN SPRING 48 AND T30 TO BETWEEN SPRING 48 AND R30.

PUSH THE POWER SWITCH ON. THEN PRESS AND RELEASE S1 TO CHARGE CAPACITOR C1. AS IN THE CIRCUIT ABOVE, LED1 WILL BRIEFLY FLASH AS C1 BEGINS TO CHARGE. NOW PRESS S2, AND LED2 WILL FLASH AS THE CHARGE STORED IN C1 IS DISCHARGED THROUGH S2 AND LED2. DO NOT PRESS S1 AND S2 AT THE SAME TIME SINCE THERE IS NO RESISTOR TO REDUCE CURRENT TO A SAFE LEVEL. A RESISTOR IS NOT NEEDED FOR THE BRIEF PULSES USED HERE.

3. USE A CAPACITOR TO PULSE A RELAY



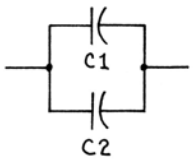
THIS BASIC CIRCUIT DOES NOT USE THE RELAY CONTACTS. LATER YOU WILL BUILD CIRCUITS THAT DO.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T28 (+) AND GROUND (-).
3. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
4. ☐ CONNECT SPRINGS 48 AND 58 (RED WIRE).
5. ☐ CONNECT SPRING 47 TO T26 (RED WIRE).
6. ☐ CONNECT SPRING 57 TO GROUND (RED WIRE).
7. ☐ CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).

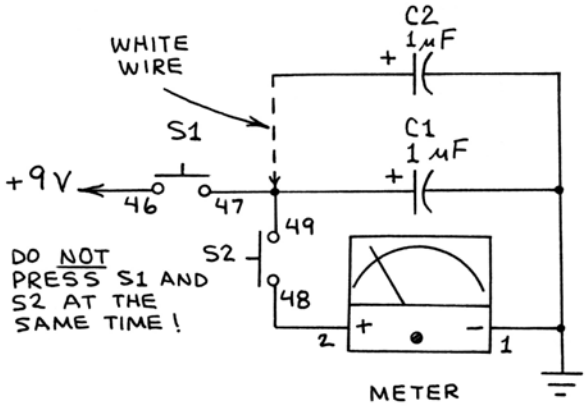
PUSH THE POWER SWITCH ON. THEN PRESS AND RELEASE S1 TO CHARGE CAPACITOR C1. NOW PRESS S2. YOU WILL HEAR A CLICK AS THE RELAY PULLS IN. THE RELAY QUICKLY DROPS OUT, BECAUSE C1 IS RAPIDLY DISCHARGED THROUGH THE RELAY COIL.

CONNECT CAPACITORS IN PARALLEL TO INCREASE CAPACITANCE

THE TOTAL CAPACITANCE OF TWO CAPACITORS IN PARALLEL IS THE SUM OF THE INDIVIDUAL CAPACITANCES. THE FORMULA IS: TOTAL C = C1 + C2. IT'S VERY COMMON TO USE CAPACITORS IN PARALLEL TO OBTAIN A HIGHER CAPACITANCE THAN AVAILABLE FROM A SINGLE CAPACITOR.



1. BUILD A CIRCUIT TO TEST TWO CAPACITORS IN PARALLEL



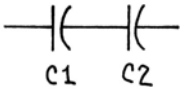
C1, C2
1 UF

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T23 (+) AND GROUND (-).
3. ☐ INSERT C2 ACROSS T30 (+) AND GROUND (-).
4. ☐ CONNECT SPRING 49 TO T21 (RED WIRE).
5. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
6. ☐ CONNECT SPRINGS 2 AND 48 (BLU WIRE).
7. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
8. ☐ INSERT A VERTICAL WHITE WIRE AT T26.
9. ☐ CONNECT SPRING 46 TO V6 (+9V) (BLU WIRE).

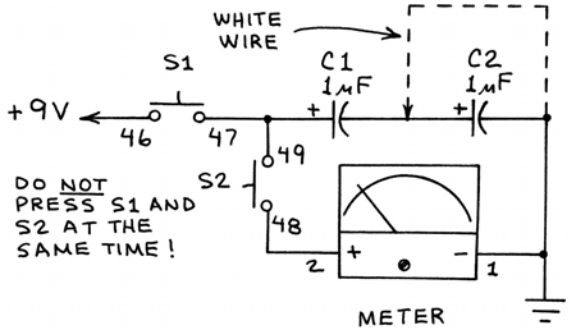
PUSH THE POWER SWITCH ON AND PRESS AND RELEASE S1 TO CHARGE C1. THEN PRESS S2 TO DISCHARGE C1 THROUGH THE METER. THE METER NEEDLE WILL MOMENTARILY JUMP UP TO ABOUT 0.08 MA. NOW INSERT THE FREE END OF THE WHITE WIRE INTO T25. PRESS AND RELEASE S1 TO CHARGE BOTH C1 AND C2. PRESS S2 AGAIN TO DISCHARGE C1 AND C2 THROUGH THE METER. THE METER NEEDLE WILL MOMENTARILY JUMP UP TO ABOUT 0.15 MA. THIS SHOWS THAT DOUBLING THE CAPACITANCE APPROXIMATELY DOUBLES THE MAXIMUM STORED CHARGE.

CONNECT CAPACITORS IN SERIES TO REDUCE CAPACITANCE

THE TOTAL CAPACITANCE OF TWO CAPACITORS IN SERIES IS THE PRODUCT OF THE TWO CAPACITANCES DIVIDED BY THEIR SUM. THE FORMULA IS: TOTAL C = (C1 X C2)/(C1 + C2).



1. BUILD A CIRCUIT TO TEST TWO CAPACITORS IN SERIES



C1, C2
1 UF

MODIFY THE CIRCUIT ABOVE BY FOLLOWING THESE STEPS:

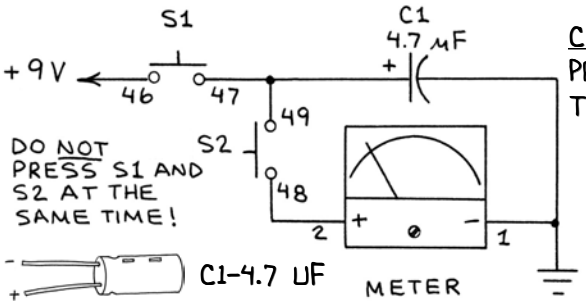
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE WHITE WIRE ACROSS T25 AND T26.
3. ☐ INSERT VERTICAL WHITE WIRE AT T28.
4. ☐ MOVE THE - LEAD OF C1 FROM GROUND TO T26.

PUSH THE POWER SWITCH ON. THEN PRESS AND RELEASE S1 TO CHARGE CAPACITORS C1 AND C2. NOW PRESS S2 WHILE WATCHING THE METER. THE NEEDLE WILL BOUNCE UP TO ABOUT 0.04 MA. NOW INSERT THE FREE END OF THE VERTICAL WHITE WIRE INTO ANY NEARBY GROUND POINT TO EFFECTIVELY REMOVE C2 FROM THE CIRCUIT. PRESS AND RELEASE S1 TO CHARGE C1. PRESS S2 AGAIN WHILE WATCHING THE METER. NOW THE NEEDLE WILL BOUNCE UP TO ABOUT 0.08 MA. THIS SHOWS THAT THE MAXIMUM CAPACITY OF TWO IDENTICAL CAPACITORS IN SERIES IS HALF THAT OF ONE OF THE CAPACITORS.

USE A CAPACITOR TO GENERATE A RAPID PULSE OF CURRENT

HERE ARE SOME SIMPLE CIRCUITS THAT SHOW MORE NEAT WAYS TO USE A CAPACITOR.

1. APPLY A PULSE TO THE METER

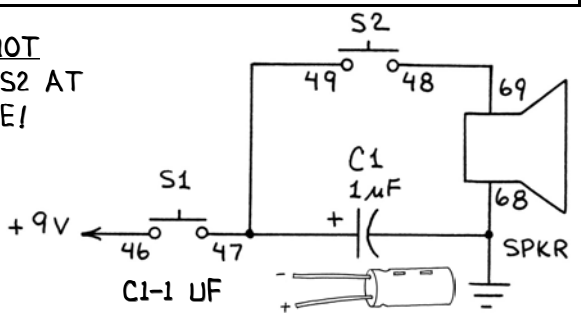


1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T26 (+) AND GROUND (–).
3. ☐ CONNECT SPRING 49 TO T30 (RED WIRE).
4. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
5. ☐ CONNECT SPRINGS 2 AND 48 (BLU WIRE).
6. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
7. ☐ CONNECT SPRING 46 TO V6 (+9V) (BLU WIRE).

THIS CIRCUIT USES ENERGY STORED IN A CAPACITOR. PUSH THE POWER SWITCH ON. PRESS S1 TO CHARGE C1. PRESS S2 TO DISCHARGE C1 THROUGH THE METER. THE NEEDLE WILL JUMP UP AND THEN QUICKLY FALL BACK AS C1 DISCHARGES.

2. APPLY A PULSE TO THE SPEAKER

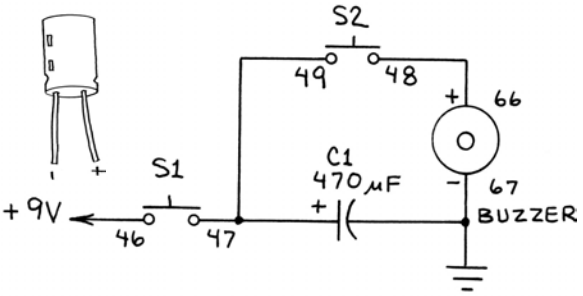
CAUTION: DO NOT PRESS S1 AND S2 AT THE SAME TIME!



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T26 (+) AND GROUND (–).
3. ☐ CONNECT SPRING 49 TO T30 (RED WIRE).
4. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
5. ☐ CONNECT SPRINGS 48 AND 69 (BLU WIRE).
6. ☐ CONNECT SPRING 68 TO GROUND (BLU WIRE).
7. ☐ CONNECT SPRING 46 TO V6 (+9V) (BLU WIRE).

THIS CIRCUIT ALSO USES ENERGY STORED IN A CAPACITOR. PUSH THE POWER SWITCH ON. PRESS S1 TO CHARGE C1. PRESS S2 TO DISCHARGE C2 THROUGH THE SPEAKER, WHICH WILL EMIT A SHARP CLICK. <u>NEVER PRESS S1 AND S2 AT THE SAME TIME.</u> THIS CAN DAMAGE THE SPEAKER.

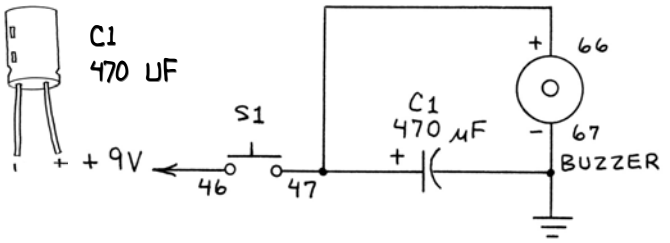
3. MAKE THE BUZZER A CHIRPER



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T26 (+) AND GROUND (–).
3. ☐ CONNECT SPRING 49 TO T30 (RED WIRE).
4. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
5. ☐ CONNECT SPRINGS 48 AND 66 (BLU WIRE).
6. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).
7. ☐ CONNECT SPRING 46 TO V6 (+9V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PUSH AND RELEASE S1 TO CHARGE C1. THEN PUSH S2. THE BUZZER WILL EMIT A BRIEF CHIRP-LIKE SOUND. THE SOUND CHANGES PITCH AS THE VOLTAGE ON C1 DECREASES.

4. MAKE THE BUZZER A WARBLER



MODIFY THE ADJACENT CIRCUIT BY FOLLOWING THESE STEPS:

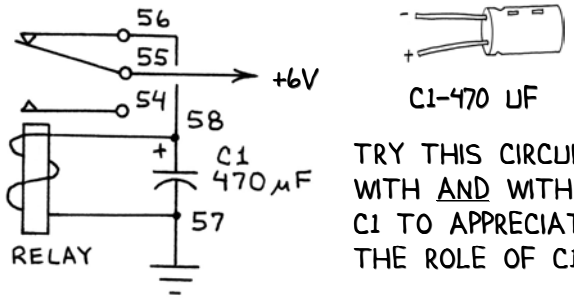
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ MOVE THE BLUE WIRE AT SPRING 48 TO SPRING 47.

PUSH THE POWER SWITCH ON. PRESS S1 AND THE BUZZER WILL EMIT A STEADY TONE. RELEASE S1, AND THE SOUND WILL RAPIDLY RISE IN PITCH AND THEN CEASE. THE SOUND CHANGES PITCH AS THE VOLTAGE ON C1 DECREASES WHEN C1 IS BEING DISCHARGED BY THE BUZZER. PRESS S1 IN A RAPID SEQUENCE TO CREATE A WARBLING SOUND.

USE A CAPACITOR WITH A RELAY CONNECTED AS AN ELECTRO-MECHANICAL BUZZER

HERE ARE SOME SIMPLE BUT NOISY CAPACITOR-RELAY CIRCUITS.

1. BUILD A RELAY CLICKER

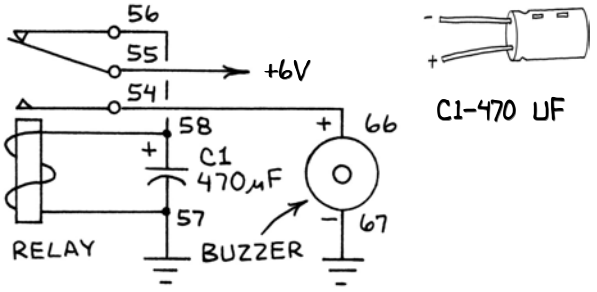


TRY THIS CIRCUIT WITH AND WITHOUT C1 TO APPRECIATE THE ROLE OF C1.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T26 (+) AND GROUND (-).
3. ☐ CONNECT SPRING 58 TO T30 (RED WIRE).
4. ☐ CONNECT SPRINGS 56 AND 58 (WHT WIRE).
5. ☐ CONNECT SPRING 57 TO GROUND (RED WIRE).
6. ☐ CONNECT SPRING 55 TO V4 (+6V) (BLU WIRE).

THE RELAY IS CONNECTED AS AN ELECTRO-MECHANICAL BUZZER. PUSH THE POWER SWITCH ON, AND C1 WILL SLOW THE BUZZ TO A SERIES OF CLICKS BY KEEPING THE RELAY ACTUATED WHILE C1 DISCHARGES.

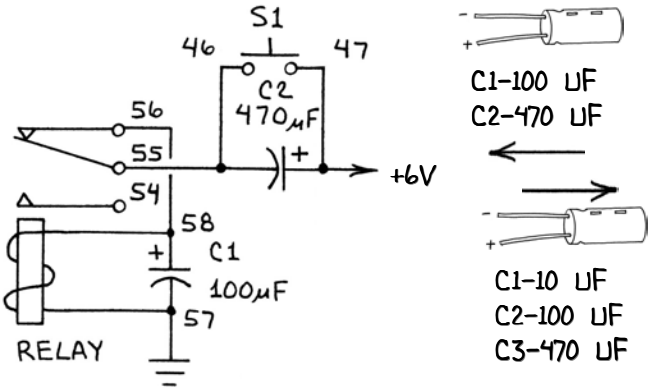
2. BUILD A PULSATING BUZZER



1. ☐ BUILD THE ADJACENT CIRCUIT FIRST.
2. ☐ CONNECT SPRINGS 54 AND 66 (RED WIRE).
3. ☐ CONNECT SPRINGS 57 AND 67 (RED WIRE).

PUSH THE POWER SWITCH ON AND THE BUZZER WILL PULSE IN STEP WITH THE BUZZING RELAY. EACH TIME THE RELAY PULLS IN, THE BUZZER IS SWITCHED ON THROUGH THE RELAY CONTACTS AT SPRINGS 54 AND 55.

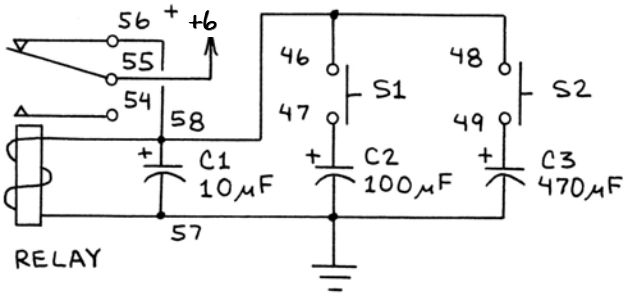
3. BUILD A DAMPED RELAY CLICKER



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T28 (+) AND GROUND (-).
3. ☐ INSERT C2 ACROSS SPRINGS 47 (+) AND 46 (-).
4. ☐ CONNECT SPRING 58 TO T30 (RED WIRE).
5. ☐ CONNECT SPRINGS 56 AND 58 (WHT WIRE).
6. ☐ CONNECT SPRINGS 46 AND 55 (RED WIRE).
7. ☐ CONNECT SPRING 57 TO GROUND (RED WIRE).
8. ☐ CONNECT SPRING 47 TO V4 (+6V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS AND RELEASE S1. THE RELAY WILL BUZZ WHEN S1 IS DOWN AND QUICKLY SLOW TO A HALT WHEN YOU RELEASE S1.

4. BUILD A VARIABLE CLICKER



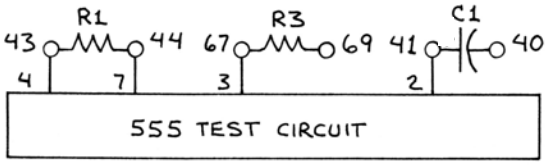
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS SPRINGS 58 (+) AND 57 (-).
3. ☐ INSERT C2 ACROSS T25 (+) AND GROUND (-).
4. ☐ INSERT C3 ACROSS T30 (+) AND GROUND (-).
5. ☐ CONNECT SPRINGS 56 AND 58 (WHT WIRE).
6. ☐ CONNECT SPRINGS 46 AND 48 (WHT WIRE).
7. ☐ CONNECT SPRING 47 TO T21 (RED WIRE).
8. ☐ CONNECT SPRING 49 TO T26 (RED WIRE).
9. ☐ CONNECT SPRINGS 48 AND 58 (RED WIRE).
10. ☐ CONNECT SPRING 57 TO GROUND (RED WIRE).
11. ☐ CONNECT SPRING 55 TO V4 (+6V) (BLU WIRE).

PUSH THE POWER SWITCH ON, AND THE RELAY WILL BUZZ. PRESS S1 AND/OR S2 TO SLOW THE BUZZ TO CLICKS.

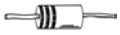
APPLY WHAT YOU'VE LEARNED: CAPACITORS AND THE "BLACK BOX" TEST CIRCUIT

YOU WILL USE CAPACITORS TO CONTROL THE TONE FROM THE "BLACK BOX" TEST CIRCUIT ON PAGE 19. THE DIAGRAMS SHOW ONLY CHANGES MADE TO THE BLACK BOX TEST CIRCUIT, SO, AS WITH THE RESISTOR CIRCUITS ON PP. 30–31, BE SURE TO BUILD EACH CIRCUIT IN ORDER.

1. PREPARE THE 555 TEST CIRCUIT AND SET THE TONE FREQUENCY WITH A CAPACITOR (C1)



C1–0.1 µF (104)



R1–10K (BRN-BLK-ORG)
R3–470 (YEL-VIO-BRN)

BE SURE THE "BLACK BOX" TEST CIRCUIT IS CONNECTED PROPERLY AND THE DPDT SWITCH IS PUSHED DOWN. REPLACE ANY WIRES THAT HAVE COME LOOSE. PUSH THE POWER SWITCH ON. THE SPEAKER WILL EMIT A 1,000-HZ TONE.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS SPRINGS 43 AND 44.
3. ☐ INSERT R3 ACROSS SPRINGS 67 AND 69.
4. ☐ INSERT C1 ACROSS SPRINGS 40 AND 41. (BE SURE THE 555 IS CONNECTED TO +6V.)

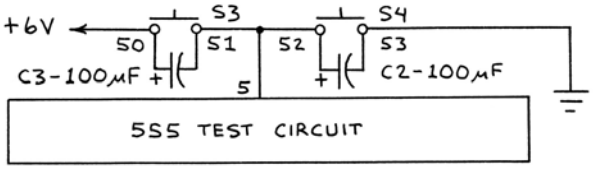
2. USE A CAPACITOR TO GENERATE A FALLING TONE

C2–100 µF

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT C2 ACROSS SPRINGS 52 (+) AND 53 (–).
3. ☐ CONNECT SPRING 53 TO GROUND (RED WIRE). (SAVE THIS CIRCUIT FOR THE NEXT PROJECT.)

PUSH THE POWER SWITCH ON. THE TEST CIRCUIT WILL EMIT A 1,000 HZ TONE. NOW PRESS AND RELEASE S4. THE TONE WILL BECOME A VERY HIGH FREQUENCY THAT FALLS DOWN TO THE ORIGINAL FREQUENCY. TRY LARGER CAPACITORS FOR C1 FOR DIFFERENT EFFECTS.

3. ADD A SECOND CAPACITOR TO GENERATE A SELECTABLE FALLING-RISING TONE

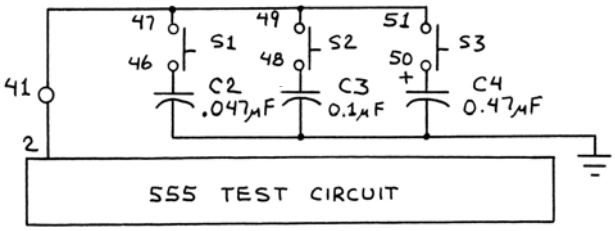


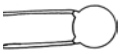
C3–100 µF

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT C3 ACROSS SPRINGS 50 (+) AND 51 (–).
3. ☐ CONNECT SPRINGS 51 AND 52 (WHT WIRE).
4. ☐ CONNECT SPRING 50 TO V4 (+6V) (BLU WIRE).

PUSH THE POWER SWITCH ON. THE CIRCUIT WILL EMIT A 1,000-HZ TONE. PRESS AND RELEASE S3, AND THE FREQUENCY OF THE TONE WILL FALL SHARPLY AND THEN RISE BACK TO THE ORIGINAL FREQUENCY. FOR NEAT SOUND EFFECTS, PUSH S3 AND S4 IN VARIOUS PATTERNS.

4. USE CAPACITORS AND A "KEYBOARD" TO CONTROL THE TONE FREQUENCY





C2–.047 µF, C3–0.1

C4–0.47 µF

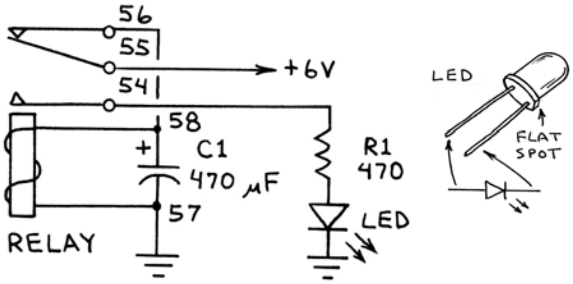
PUSH THE POWER SWITCH ON. THE CIRCUIT WILL EMIT A 1,000-HZ TONE. REMOVE C1 FROM SPRINGS 40 AND 41, AND THE TONE WILL CEASE. PRESS S1, S2 AND S3 IN SEQUENCE TO PRODUCE A SERIES OF TONES. PRESS MORE THAN ONE SWITCH TO PRODUCE MORE TONES.

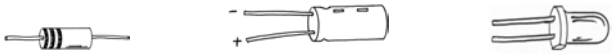
1. ☐ REMOVE OLD C2 AND C3 FROM PREVIOUS CIRCUIT.
2. ☐ REMOVE BLUE WIRE ACROSS SPRING 50 AND V4.
3. ☐ REMOVE WHITE WIRE ACROSS SPRINGS 51 AND 52.
4. ☐ INSERT C2 ACROSS SPRING 46 (+) AND GROUND (–).
5. ☐ INSERT C3 ACROSS SPRING 48 (+) AND GROUND (–).
6. ☐ INSERT C4 ACROSS SPRING 50 (+) AND GROUND (–).
7. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
8. ☐ CONNECT SPRINGS 49 AND 51 (WHT WIRE).
9. ☐ CONNECT SPRINGS 41 AND 47 (RED WIRE).

RESISTOR AND CAPACITOR CIRCUITS

THE CIRCUITS YOU HAVE BUILT SO FAR USE EITHER RESISTORS OR CAPACITORS. COMBINING RESISTORS AND CAPACITORS OPENS A HUGE NEW WORLD OF APPLICATIONS. LET'S BEGIN WITH SOME BASIC CIRCUITS THAT YOU CAN QUICKLY BUILD.

1. BUILD A FLICKERING LED CIRCUIT USING A RELAY



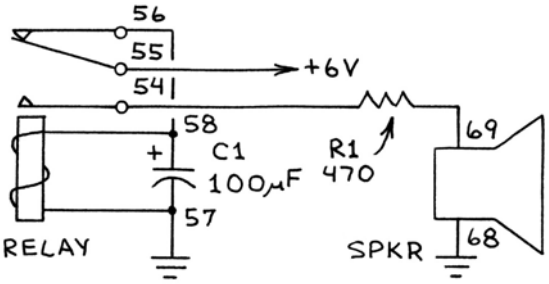


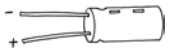
R1-470 (YEL-VIO-BRN) C1-470 UF LED-RED LED

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T26 (+) AND GROUND (-).
3. ☐ CONNECT SPRING 58 TO T30 (RED WIRE).
4. ☐ CONNECT SPRINGS 56 AND 58 (WHT WIRE).
5. ☐ CONNECT SPRING 57 TO GROUND (RED WIRE).
6. ☐ CONNECT SPRING 55 TO V4 (+6V) (BLU WIRE).
7. ☐ INSERT LED ACROSS T21 (ANODE) AND GROUND (CATHODE).
8. ☐ INSERT R1 ACROSS T23 AND P23.
9. ☐ CONNECT SPRING 54 TO P25 (RED WIRE).

CHECK TO MAKE SURE THERE ARE NO ERRORS. THEN PUSH THE POWER SWITCH TO ON. THE RELAY WILL CHATTER, AND THE LED WILL FLICKER IN STEP WITH THE RELAY. LOOK CLOSELY AT THE LED TO SEE THE FLICKER. C1 SLOWS THE RELAY FROM A WHINE TO A CHATTER. R1 LIMITS THE CURRENT TO THE LED.

2. BUILD A PULSATING SPEAKER CIRCUIT USING A RELAY





C1-100 UF

MODIFY THE ABOVE CIRCUIT BY FOLLOWING THESE STEPS:

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE THE LED.
3. ☐ REMOVE OLD C1 (470 UF)
4. ☐ INSERT NEW C1 ACROSS T26 (+) AND GROUND (-).
5. ☐ CONNECT SPRINGS 57 AND 68 (RED WIRE).
6. ☐ CONNECT SPRING 69 TO T25 (BLU WIRE).

CHECK YOUR WIRING FOR ERRORS. PUSH THE POWER SWITCH ON, AND YOU WILL HEAR A BUZZ FROM THE SPEAKER. EACH CLOSURE OF THE RELAY CONTACTS SENDS A PULSE OF CURRENT TO THE SPEAKER.

TIME OUT FOR A QUICK REVIEW

ON THE NEXT PAGE YOU'LL LEARN ABOUT A MUCH MORE IMPORTANT WAY TO USE RESISTORS AND CAPACITORS IN THE SAME CIRCUIT. LET'S FIRST REVIEW SOME KEY CONCEPTS:

1. SWITCHES PROVIDE ON-OFF CONTROL FOR THE FLOW OF ELECTRICAL CURRENT.

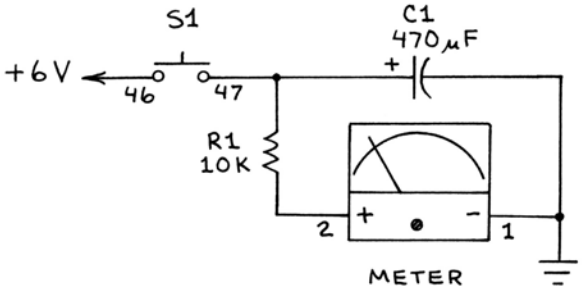
2. RESISTORS REDUCE, OR LIMIT, CURRENT. THEY PROTECT OTHER PARTS FROM BEING DAMAGED BY EXCESSIVE CURRENT.

3. CAPACITORS STORE AN ELECTRICAL CHARGE. CAPACITORS BLOCK CONTINUOUS CURRENT. A PULSED SIGNAL WILL PASS THROUGH A CAPACITOR.

RESISTOR-CAPACITOR (RC) CIRCUITS

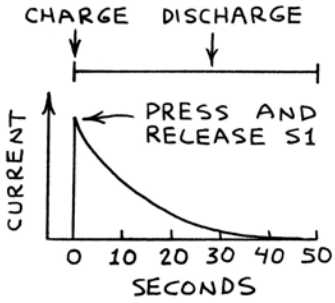
THE CIRCUITS ON THE PREVIOUS PAGE USE A RESISTOR AND A CAPACITOR INDEPENDENTLY OF ONE ANOTHER. HERE YOU WILL CONNECT A RESISTOR DIRECTLY TO A CAPACITOR TO FORM THE RC CIRCUITS THAT ARE SO VERY IMPORTANT IN ELECTRONICS.

1. BUILD A CIRCUIT THAT RAPIDLY CHARGES, AND SLOWLY DISCHARGES, A CAPACITOR



R1-10K (BRN-BLK-ORG) C1-470 UF

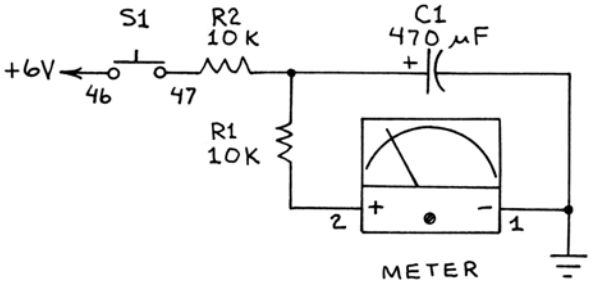
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T25 (+) AND GROUND (-).
3. ☐ INSERT R1 ACROSS T21 AND P21.
4. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
5. ☐ CONNECT SPRING 2 TO P25 (BLU WIRE).
6. ☐ CONNECT SPRING 47 TO T23 (RED WIRE).
7. ☐ CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).

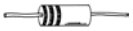


BE SURE THERE ARE NO WIRING ERRORS. PUSH THE POWER SWITCH ON. PRESS AND RELEASE S1, AND THE METER NEEDLE WILL RAPIDLY SWING UP TO ABOUT 0.6 MA, THEN SLOWLY DRIFT BACK TO 0 MA. THE GRAPH SHOWS THE RAPID CHARGE AND GRADUAL DISCHARGE.

<u>HOW IT WORKS</u>: PRESS S1 AND C1 RAPIDLY CHARGES. WHEN YOU RELEASE S1, C1 DISCHARGES THROUGH R1 AND THE METER. R1 LIMITS CURRENT FLOW FROM C1, WHICH IS WHY IT TAKES 10-15 SECONDS FOR C1 TO FULLY DISCHARGE (SEE BELOW). R1 ALSO PROTECTS THE METER.

2. BUILD A CIRCUIT THAT SLOWLY CHARGES AND SLOWLY DISCHARGES A CAPACITOR

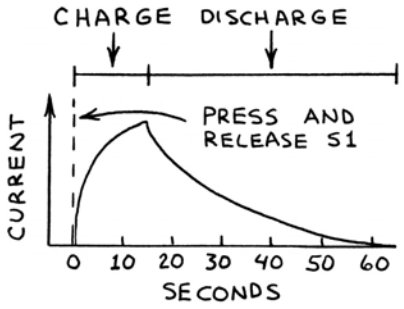




R2-10K (BRN-BLK-ORG)

MODIFY THE ABOVE CIRCUIT BY FOLLOWING THESE STEPS:

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ MOVE THE RED WIRE AT T23 TO N21.
3. ☐ INSERT R2 ACROSS T23 AND N23.



BE SURE THERE ARE NO WIRING ERRORS. PUSH THE POWER SWITCH ON. PRESS S1, AND THE METER NEEDLE WILL SLOWLY SWING UP TO 0.3 MA. RELEASE S1, AND THE NEEDLE WILL GRADUALLY DRIFT BACK TO 0 MA. SEE THE GRAPH.

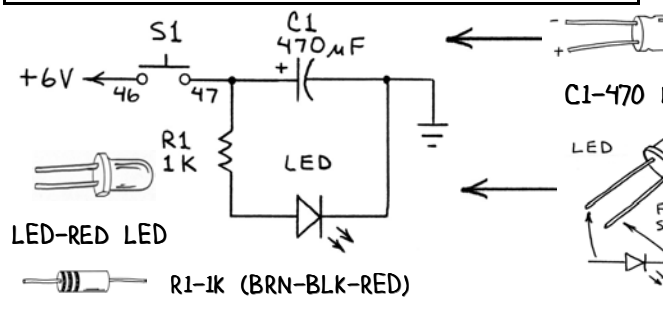
THIS CIRCUIT IS CALLED AN <u>RC INTEGRATOR</u>. R X C (OR R2 X C1) IS KNOWN AS THE <u>TIME CONSTANT</u> (T) OF THE INTEGRATOR. AT T, THE CHARGE ON C1 IS 63.2% OF SUPPLY VOLTAGE. AT 5 X T C1 IS FULLY CHARGED. THE VOLTAGE ON C1 CHANGES <u>EXPONENTIALLY</u> WITH TIME.

<u>HOW IT WORKS</u>: WHEN YOU PRESS S1, C1 SLOWLY CHARGES THROUGH R2. WHEN YOU RELEASE, S1, C1 DISCHARGES THROUGH R1 AND THE METER. R1 LIMITS CURRENT FROM C1, WHICH IS WHY IT TAKES TIME FOR C1 TO FULLY DISCHARGE.

RC CIRCUIT SAMPLER

TRY THESE SIMPLE CIRCUITS TO BETTER UNDERSTAND HOW RC CIRCUITS WORK.

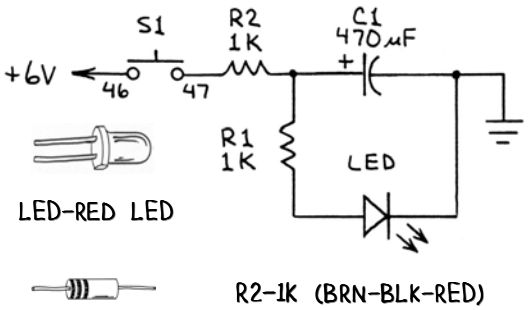
1. FADE AN LED OUT



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T30 (+) AND GROUND (-).
3. ☐ INSERT LED ACROSS T21 (ANODE) AND GROUND (CATHODE).
4. ☐ INSERT R1 ACROSS T25 AND T26.
5. ☐ CONNECT SPRING 47 TO T28 (RED WIRE).
6. ☐ CONNECT SPRING 46 TO V4 (+6V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS S1, AND THE LED WILL GLOW. RELEASE S1, AND THE LED WILL GRADUALLY FADE OUT.

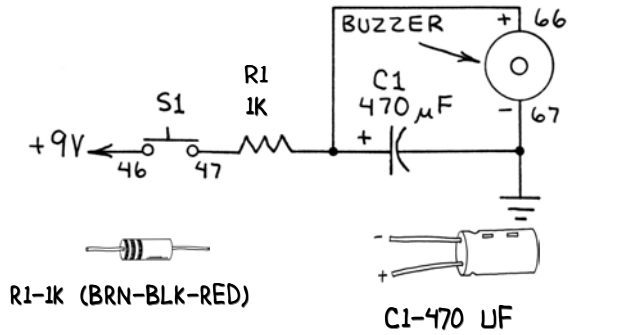
2. FADE AN LED IN AND OUT



1. ☐ BUILD THE ADJACENT CIRCUIT FIRST.
2. ☐ MOVE RED WIRE AT T28 TO P26.
3. ☐ INSERT R2 ACROSS T28 AND P28.

PUSH THE POWER SWITCH ON. PRESS S1 AND THE LED WILL GRADUALLY BRIGHTEN. RELEASE S1, AND THE LED WILL GRADUALLY FADE OUT. INCREASE R1 TO 10K (BRN-BLK-ORG) FOR MORE GRADUAL OPERATION. NOTE THAT THE LED IS POWERED DIRECTLY BY C1 IN THIS AND THE ADJACENT CIRCUIT.

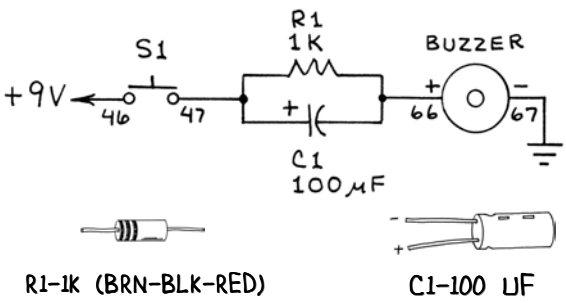
3. GENERATE A "BIRD" CHIRP



1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T30 (+) AND GROUND (-).
3. ☐ INSERT R1 ACROSS T25 AND T26.
4. ☐ CONNECT SPRING 66 TO T28 (BLU WIRE).
5. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).
6. ☐ CONNECT SPRING 47 TO T21 (RED WIRE).
7. ☐ CONNECT SPRING 46 TO V6 (+9V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS AND RELEASE S1, AND THE BUZZER WILL EMIT A "BIRD" CHIRP. SHORT R1 WITH A RED WIRE FROM T24 TO T27 TO HEAR A DIFFERENT CHIRP. PRESS S1 RAPIDLY FOR A WARBLE.

4. GENERATE A "HARD" CHIRP



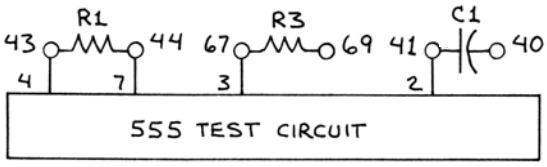
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS T25 (+) AND T26 (-).
3. ☐ INSERT R1 ACROSS T24 AND T27.
4. ☐ CONNECT SPRING 66 TO T30 (BLU WIRE).
5. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).
6. ☐ CONNECT SPRING 47 TO T21 (RED WIRE).
7. ☐ CONNECT SPRING 46 TO V6 (+9V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS AND RELEASE S1, AND THE BUZZER WILL EMIT A SHARP, HIGH-PITCHED CHIRP. IN THIS CIRCUIT R1 DOES NOT LIMIT CURRENT TO C1. INSTEAD, R1 DISCHARGES C1 AFTER C1 IS CHARGED.

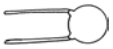
APPLY WHAT YOU'VE LEARNED: RC CIRCUITS AND THE "BLACK BOX" TEST CIRCUIT

YOU WILL USE AN RC CIRCUIT TO CHANGE THE VOLTAGE AT THE CONTROL INPUT OF THE "BLACK BOX" TEST CIRCUIT ON PAGE 19. THE DIAGRAMS SHOW ONLY CHANGES MADE TO THE BLACK BOX TEST CIRCUIT, SO BE SURE TO BUILD EACH CIRCUIT IN ORDER.

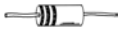
1. PREPARE THE 555 TEST CIRCUIT AND SET THE TONE FREQUENCY WITH A CAPACITOR (C1)



BE SURE THE 555 TEST CIRCUIT IS CONNECTED PROPERLY AND THE DPDT SWITCH IS PUSHED DOWN. REPLACE THE SPEAKER WIRES AND ANY OTHER WIRES THAT HAVE COME LOOSE.



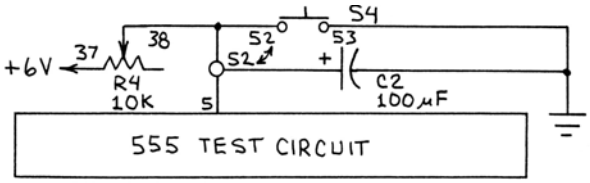
C1-0.1 UF (104)



R1-10K (BRN-BLK-ORG)
R3-470 (YEL-VIO-BRN)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS SPRINGS 43 AND 44.
3. ☐ INSERT R3 ACROSS SPRINGS 67 AND 69.
4. ☐ INSERT C1 ACROSS SPRINGS 40 AND 41. (BE SURE THE 555 IS CONNECTED TO +6V.)

2. USE AN ADJUSTABLE RC CIRCUIT TO CREATE "SPACE GUN" SOUND EFFECTS

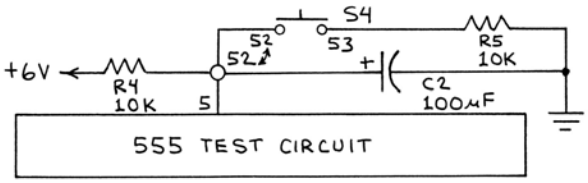


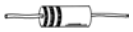
C2-100 UF

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C2 ACROSS T26 (+) AND GROUND (-).
3. ☐ CONNECT SPRING 52 TO T30 (WHT WIRE).
4. ☐ CONNECT SPRING 53 TO GROUND (RED WIRE).
5. ☐ CONNECT SPRING 38 TO T28 (BLU WIRE).
6. ☐ CONNECT SPRING 37 TO V4 (+6V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS AND RELEASE S4 TO CREATE A SOUND MUCH LIKE THAT OF SCIENCE FICTION SPACE GUNS. RAPIDLY PRESS AND RELEASE S4 FOR BEST RESULTS.

3. USE A SWITCHED RC CIRCUIT TO CREATE SIREN SOUNDS



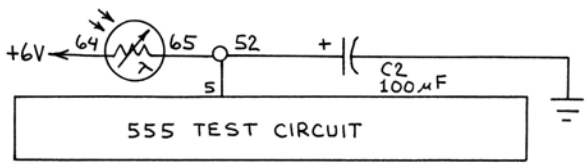


R4, R5-10K (BRN-BLK-ORG)

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE RED WIRE FROM SPRING 53 TO GROUND.
3. ☐ REMOVE BLUE WIRES ACROSS SPRINGS 37 AND 38 AND V4 (+6V) AND T28.
4. ☐ INSERT R4 ACROSS T28 AND P28.
5. ☐ INSERT R5 ACROSS S30 AND GROUND.
6. ☐ CONNECT SPRING 53 TO S29 (RED WIRE).
7. ☐ CONNECT P26 TO V4 (+6V) (BLU WIRE).

PUSH THE POWER SWITCH ON, AND THE CIRCUIT WILL EMIT A STEADY TONE. PRESS S4, AND THE FREQUENCY OF THE TONE WILL RISE. RELEASE S4 AND THE FREQUENCY WILL FALL. PRESS AND RELEASE S4 TO CREATE SIREN-LIKE SOUNDS. OK TO TRY OTHER VALUES FOR R4.

4. USE A LIGHT-SENSITIVE RC CIRCUIT TO CONTROL THE TEST CIRCUIT'S TONE



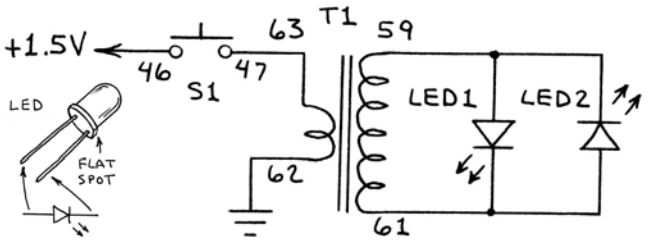
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE R4 AND R5.
3. ☐ REMOVE RED WIRE ACROSS SPRING 53 AND S29.
4. ☐ CONNECT SPRINGS 65 AND 52 (BLU WIRE).
5. ☐ CONNECT SPRING 64 TO V4 (+6V) (BLU WIRE).

PUSH THE POWER SWITCH ON. THE CIRCUIT WILL EMIT A TONE. SHINE LIGHT ON THE PHOTORESISTOR, AND THE TONE FREQUENCY WILL DECREASE. BLOCK THE PHOTORESISTOR WITH YOUR FINGER, AND THE TONE FREQUENCY WILL INCREASE.

THE CONSOLE TRANSFORMER

THE TRANSFORMER INSTALLED IN YOUR LEARNING LAB CONSISTS OF TWO COILS OF WIRE WOUND AROUND THIN IRON PLATES. ONE COIL HAS MANY TURNS OF WIRE (SPRINGS 59 AND 61 WITH A CENTER TAP AT SPRING 60). THE OTHER COIL HAS FEWER TURNS (SPRINGS 62 AND 63). THE TRANSFORMER CAN BOOST A SMALL VOLTAGE APPLIED TO THE COIL WITH A FEW TURNS TO A LARGER VOLTAGE AT THE COIL WITH MANY TURNS. MANY CIRCUITS CANNOT BE CONNECTED DIRECTLY TO AN ELECTROMAGNETIC SPEAKER, SINCE THE RESISTANCE OF SUCH SPEAKERS IS VERY LOW. A TRANSFORMER CAN BE USED TO MATCH THE OUTPUT OF SUCH CIRCUITS TO A SPEAKER. YOU WILL NEXT EXPERIMENT WITH BOTH THESE TRANSFORMER APPLICATIONS.

1. USE A TRANSFORMER TO BOOST A SMALL VOLTAGE TO A HIGHER VOLTAGE



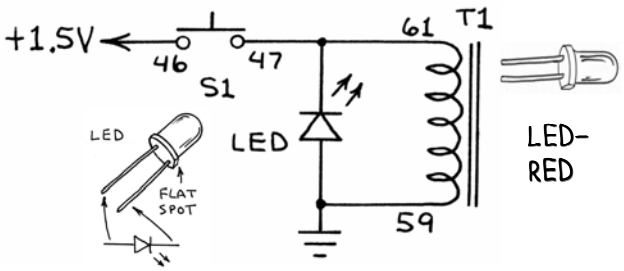
PUSH THE POWER SWITCH ON. PRESS S1 AND LED 1 WILL FLASH. QUICKLY RELEASE S1 AND LED 2 WILL FLASH. SINCE THE LEDS REQUIRE MORE THAN 1.5 VOLTS TO EMIT LIGHT, THIS PROVES THAT THE TRANSFORMER BOOSTS 1.5 VOLTS TO A HIGHER VOLTAGE. MOVE THE RED WIRE AT SPRING 59 TO SPRING 60 AND REPEAT. THE FLASHES WILL BE DIMMER SINCE ONLY HALF THE TRANSFORMER WINDING IS USED.

LED 1-RED, LED 2-GREEN

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT RED LED 1 ACROSS Q26 (ANODE) AND T26 (CATHODE).
3. ☐ INSERT GREEN LED 2 ACROSS Q30 (CATHODE) AND T30 (ANODE).
4. ☐ CONNECT SPRING 59 TO Q28 (RED WIRE).
5. ☐ CONNECT SPRING 61 TO T28 (BLU WIRE).
6. ☐ CONNECT SPRINGS 47 AND 63 (BLU WIRE).
7. ☐ CONNECT SPRING 62 TO GROUND (RED WIRE).
8. ☐ CONNECT SPRING 46 TO V1 (+1.5V) (BLU WIRE).

THE LEDS FLASH ONCE PER SWITCH CLOSURE SINCE THE TRANSFORMER BOOSTS ONLY PULSES, NOT CONTINUOUS CURRENT.

2. USE HALF A TRANSFORMER TO BOOST A VOLTAGE TO A HIGHER VOLTAGE

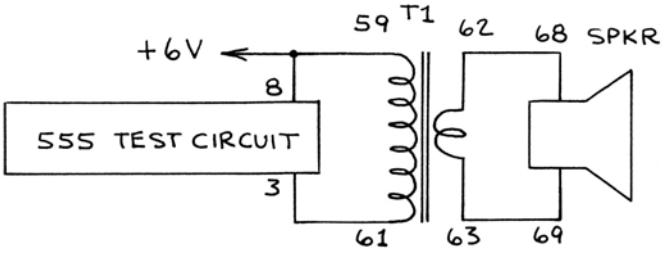


LED-RED

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT RED LED ACROSS T26 (CATHODE) AND GROUND (ANODE).
3. ☐ CONNECT SPRING 59 TO GROUND (RED WIRE).
4. ☐ CONNECT SPRING 47 TO T28 (RED WIRE).
5. ☐ CONNECT SPRING 61 TO T30 (RED WIRE).
6. ☐ CONNECT SPRING 46 TO V1 (+1.5V) (BLU WIRE).

PUSH THE POWER SWITCH ON. PRESS AND RELEASE S1, AND THE LED FLASHES AS VOLTAGE ACROSS T1'S COIL COLLAPSES AND IS INCREASED ENOUGH TO LIGHT THE LED.

3. USE A TRANSFORMER TO DRIVE A SPEAKER



1. ☐ BUILD THE 555 TEST CIRCUIT ON PAGE 19.
2. ☐ MOVE THE BLU WIRE AT SPRING 67 TO SPRING 61.
3. ☐ MOVE THE BLU WIRE AT SPRING 68 TO SPRING 59.
4. ☐ CONNECT SPRINGS 62 AND 68 (RED WIRE).
5. ☐ CONNECT SPRINGS 63 AND 69 (RED WIRE).

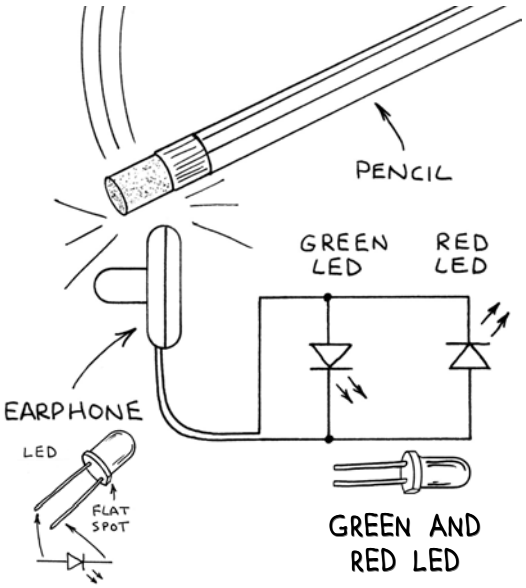
PUSH THE POWER SWITCH ON. THE SPEAKER WILL EMIT A VERY PURE TONE. THE TRANSFORMER PROVIDES A GOOD MATCH BETWEEN THE 555 OSCILLATOR AND THE SPEAKER.

THE TRANSDUCERS AND HOW THEY WORK

TRANSDUCERS CONVERT ONE FORM OF ENERGY INTO ANOTHER. MANY TRANSDUCERS ARE REVERSIBLE. THUS A TRANSDUCER THAT CHANGES A CURRENT TO SOUND MAY CHANGE SOUND INTO A CURRENT. THE TRANSDUCERS IN YOUR LEARNING LAB ARE THE CERAMIC EARPHONE, THE SPEAKER AND THE CERAMIC ELEMENT INSIDE THE BUZZER.

1. USE THE CERAMIC EARPHONE BACKWARDS TO GENERATE A VOLTAGE

YOUR LEARNING LAB EARPHONE USES A PIEZOELECTRIC CERAMIC DISK TO TRANSFORM VOLTAGE INTO SOUND. AS SHOWN HERE, THE EARPHONE CAN ALSO ACT AS A MICROPHONE.

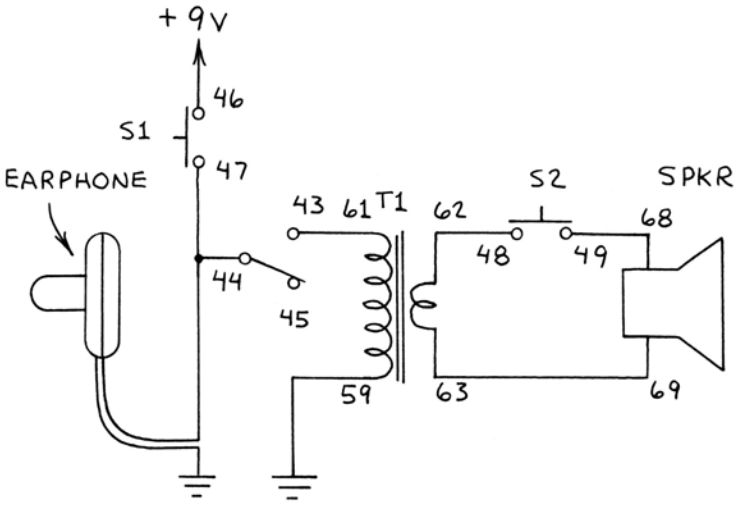


1. ☐ INSERT RED LED 1 ACROSS R1 (CATHODE) AND T1 (ANODE).
2. ☐ INSERT GREEN LED 2 ACROSS R5 (ANODE) AND T5 (CATHODE).
3. ☐ CONNECT ONE EARPHONE LEAD TO SPRING 40.
4. ☐ CONNECT SECOND EARPHONE LEAD TO SPRING 43.
5. ☐ CONNECT SPRING 40 TO R3 (RED WIRE).
6. ☐ CONNECT SPRING 43 TO T3 (RED WIRE).

ASSEMBLE THE CIRCUIT. THEN DARKEN THE ROOM LIGHTS, HOLD THE EARPHONE AND TAP IT SHARPLY WITH A PENCIL. THE TWO LEDS WILL FLASH EACH TIME YOU TAP THE EARPHONE. SINCE THE LEDS HAVE A TURN-ON VOLTAGE OF A FEW VOLTS, THE PHONE GENERATES AT LEAST THIS MUCH VOLTAGE WHEN STRUCK BY THE PENCIL.

2. APPLY A HIGH-VOLTAGE PULSE TO THE EARPHONE TO GENERATE A POPPING SOUND

YOU WILL APPLY A HIGH-VOLTAGE PULSE TO THE EARPHONE TO GENERATE A SHARP SOUND.



PUSH THE DPDT SWITCH DOWN AND THE POWER SWITCH ON. PRESS AND RELEASE S1 AND THE EARPHONE WILL GENERATE A SOFT CLICK AS 9-VOLTS ARE APPLIED TO IT. NOW PUSH THE DPDT SWITCH UP AND PRESS S1. WHEN YOU RELEASE S1, A HIGH VOLTAGE PULSE FROM THE TRANSFORMER WILL GENERATE A LOUD POP FROM THE EARPHONE. REPEAT THIS WHILE PRESSING S2, AND THE SPEAKER WILL EMIT A SOFT CLICK WHEN S1 IS PRESSED AND A LOUD POP WHEN S1 IS RELEASED.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT ONE EARPHONE LEAD TO SPRING 41.
3. ☐ CONNECT SECOND EARPHONE LEAD TO SPRING 44.
4. ☐ CONNECT SPRINGS 44 AND 47 (WHT WIRE).
5. ☐ CONNECT SPRINGS 41 AND 59 (BLU WIRE).
6. ☐ CONNECT SPRINGS 43 AND 61 (BLU WIRE).
7. ☐ CONNECT SPRINGS 63 AND 69 (RED WIRE).
8. ☐ CONNECT SPRINGS 48 AND 62 (RED WIRE).
9. ☐ CONNECT SPRINGS 49 AND 68 (BLU WIRE).
10. ☐ CONNECT SPRING 59 TO GROUND (RED WIRE).
11. ☐ CONNECT SPRING 46 TO V6 (+9V) (BLU WIRE).

SILICON DIODES AND HOW TO USE THEM

SILICON DIODES ARE SEMICONDUCTOR DEVICES THAT PASS AN ELECTRICAL CURRENT IN ONE DIRECTION ONLY. THEY CONDUCT ONLY WHEN THE VOLTAGE ACROSS THEM EXCEEDS ABOUT 0.6 VOLT, WHICH MAKES POSSIBLE MANY IMPORTANT APPLICATIONS.

BUILD A 2-VOLT DIODE VOLTAGE REGULATOR

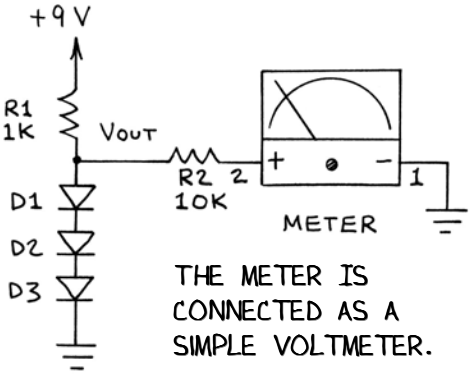
YOU WILL USE A STRING OF THREE STANDARD DIODES (NOT ZENER DIODES) AS A VOLTAGE REGULATOR THAT PROVIDES A STEADY OUTPUT OF ABOUT 2 VOLTS.

PARTS YOU WILL NEED

R1-1K (BRN-BLK-RED)
R2-10K (BRN-BLK-ORG)

D1, D2, D3-1N4148 DIODE

CIRCUIT DIAGRAM



THE METER IS CONNECTED AS A SIMPLE VOLTMETER.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS C25 AND C28.
3. ☐ INSERT R2 ACROSS C23 AND G26.
4. ☐ INSERT D1 ACROSS C21 (ANODE) AND J21 (CATHODE).
5. ☐ INSERT D2 ACROSS J25 (ANODE) AND P25 (CATHODE).
6. ☐ INSERT D3 ACROSS P21 (ANODE) AND GROUND (CATHODE).
7. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
8. ☐ CONNECT SPRING 2 TO G30 (BLU WIRE).
9. ☐ CONNECT C30 AND V6 (+9V) (RED WIRE).

BE SURE TO CHECK YOUR WIRING FOR ERRORS. BE SURE R2 IS 10K TO PROTECT THE METER.

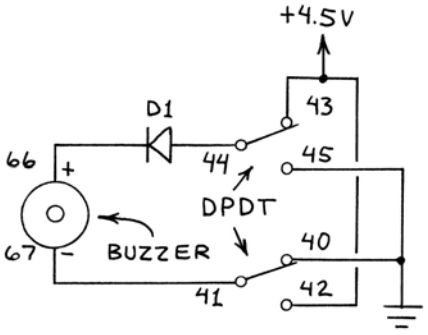
2. TEST THE CIRCUIT

PUSH THE POWER SWITCH ON. THE METER WILL INDICATE ABOUT 0.2 MA--WHICH IS EQUIVALENT TO 2 VOLTS. MOVE THE RED WIRE AT V6 TO V5 (+7.5V), V4 (+6V) AND THEN V3 (+4.5V) AND THE METER WILL CONTINUE TO INDICATE ABOUT 2 VOLTS AT EACH INPUT VOLTAGE.

BUILD A DIODE REVERSE VOLTAGE PROTECTION CIRCUIT

YOU WILL BUILD A CIRCUIT TO PROTECT THE BUZZER FROM REVERSE (BACKWARDS) POLARITY.

CIRCUIT DIAGRAM



D1-1N4148

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT D1 ACROSS T18 (ANODE) AND T23 (CATHODE).
3. ☐ CONNECT SPRING 44 TO T16 (RED WIRE).
4. ☐ CONNECT SPRING 66 TO T25 (BLU WIRE).
5. ☐ CONNECT SPRINGS 41 AND 67 (YEL WIRE).
6. ☐ CONNECT SPRINGS 40 AND 45 (WHT WIRE).
7. ☐ CONNECT SPRINGS 42 AND 43 (WHT WIRE).
8. ☐ CONNECT SPRING 40 TO GROUND (RED WIRE).
9. ☐ CONNECT SPRING 43 TO V3 (+4.5V) (BLU WIRE).

2. TEST THE CIRCUIT

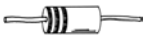
PUSH THE POWER SWITCH ON. PUSH THE DPDT SWITCH UP, AND THE BUZZER WILL SOUND. PUSH IT DOWN, AND THE BUZZER WILL BE SILENT. THE DIODE PROTECTS THE BUZZER FROM REVERSE POLARITY WHEN THE DPDT SWITCH IS DOWN.

NOTE: A PRACTICAL CIRCUIT WILL USE A SECOND

BUILD A DIODE VOLTAGE DROPPER

A SILICON DIODE BEGINS TO CONDUCT OR TURN ON AT ABOUT 0.6 VOLT. YOU WILL CONNECT A STRING OF DODES IN SERIES TO PROVIDE THREE DIFFERENT VOLTAGES FROM A SINGLE SUPPLY.

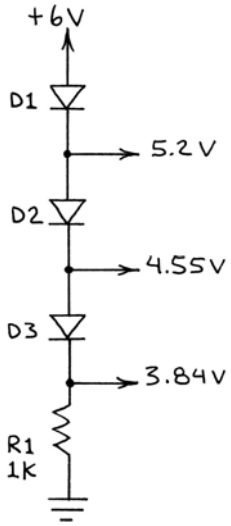
PARTS YOU WILL NEED

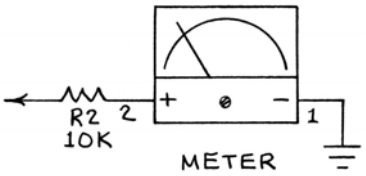


R1-1K (BRN-BLK-RED)
R2-10K (BRN-BLK-ORG)

D1, D2, D3-DIODE

CIRCUIT DIAGRAM





THIS IS A SIMPLE VOLT METER (1 MA = 10 VOLTS).

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT D1 ACROSS V4 (+6V) (ANODE) AND G16 (CATHODE).
3. ☐ INSERT D2 ACROSS G20 (ANODE) AND N20 (CATHODE).
4. ☐ INSERT D3 ACROSS N16 (ANODE) AND T16 (CATHODE).
5. ☐ INSERT R1 ACROSS T20 AND GROUND.
6. ☐ INSERT R2 ACROSS A25 AND A29.
7. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
8. ☐ CONNECT SPRING 2 TO A30 (BLU WIRE).
9. ☐ INSERT A VERTICAL RED WIRE AT A21.

2. TEST THE CIRCUIT

PUSH THE POWER SWITCH ON. THEN INSERT THE FREE END OF THE VERTICAL RED WIRE INTO T18 (BETWEEN R1 AND D3). THE METER WILL INDICATE ABOUT 0.38 MA--WHICH IS EQUIVALENT TO 3.8 VOLTS. MOVE THE RED WIRE TO N18 (BETWEEN D3 AND D2), AND THE METER WILL INDICATE ABOUT 4.5 VOLTS. MOVE THE RED WIRE TO G18 (BETWEEN D2 AND D1) AND THE METER WILL INDICATE ABOUT 5.2 VOLTS. YOU MAY GET SLIGHTLY DIFFERENT VOLTAGES.

BUILD A DIODE POP AND CRACKLE SUPPRESSOR

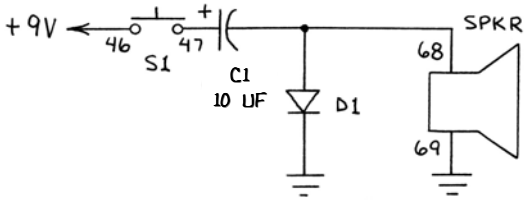
LIGHTNING AND ELECTRICAL PULSES CAN CAUSE LOUD POPS AND CRACKLES FROM A SPEAKER CONNECTED TO AN AMPLIFIER. YOU WILL USE A DIODE TO FORM A PATH FOR SIGNALS THAT EXCEED ABOUT 0.6 VOLT, THEREBY STEERING THEM AWAY FROM THE SPEAKER.

PARTS YOU WILL NEED

C1-10 UF

D1-DIODE

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS P25 (+) AND P26 (−).
3. ☐ INSERT D1 ACROSS P28 (ANODE) AND GROUND (CATHODE).
4. ☐ CONNECT SPRING 68 TO P30 (BLU WIRE).
5. ☐ CONNECT SPRING 69 TO GROUND (BLU WIRE).
6. ☐ CONNECT SPRING 47 TO P21 (RED WIRE).
7. ☐ CONNECT SPRING 46 TO V6 (+9V) (BLU WIRE).

2. TEST THE CIRCUIT

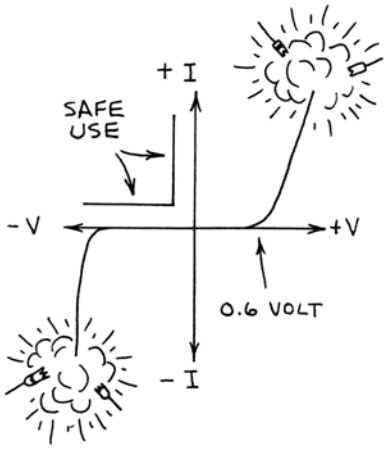
PUSH THE POWER SWITCH ON. PRESS S1, AND THE SPEAKER WILL EMIT A SOFT CLICK. THEN REMOVE DIODE D1 FROM THE CIRCUIT AND PRESS S1. THIS TIME THE SPEAKER WILL EMIT A LOUDER CLICK OR POP. DISCHARGE C1 BETWEEN TESTS BY TOUCHING EACH END OF A SPARE RED WIRE ACROSS ITS LEADS. HOW CAN YOU ABSORB NEGATIVE (−) PULSES? EASY. JUST ADD A SECOND DIODE ACROSS D1 BUT ALIGNED IN THE OPPOSITE DIRECTION.

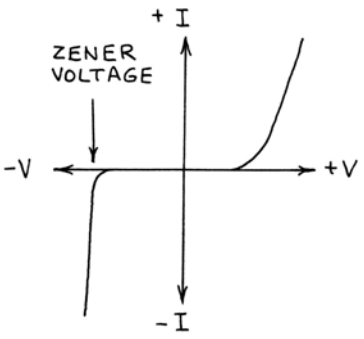
NOTE: A PRACTICAL CIRCUIT WILL USE A SECOND

ZENER DIODES AND HOW TO USE THEM

YOU ALREADY KNOW HOW A DIODE ALLOWS CURRENT TO FLOW IN ONLY ONE DIRECTION. THE ZENER DIODE ACTS LIKE A STANDARD DIODE WHEN CONNECTED BACKWARDS, UNTIL THE VOLTAGE REACHES A CRITICAL POINT CALLED THE ZENER BREAKDOWN VOLTAGE. THE DIODE THEN CONDUCTS IN THE REVERSE DIRECTION. ZENER DIODES CAN BE MADE WITH A WIDE RANGE OF ZENER VOLTAGES. THEIR ABILITY TO CONDUCT AT THESE VERY SPECIFIC VOLTAGES GIVES THEM SOME NEAT APPLICATIONS IN REGULATING AND DETECTING VOLTAGES.

THE LEFT GRAPH SHOWS HOW A DIODE CAN SAFELY CONDUCT OR BLOCK CURRENT WITHIN A SPECIFIC RANGE OF CURRENT AND VOLTAGE. TOO MUCH CURRENT OR VOLTAGE WILL OVERHEAT OR DESTROY A DIODE.



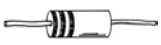


THE RIGHT GRAPH SHOWS HOW A ZENER DIODE CONDUCTS IN THE BACKWARDS DIRECTION AT A VERY SPECIFIC VOLTAGE, SUCH AS 5 VOLTS. EXCESS CURRENT OR VOLTAGE WILL ZAP A ZENER.

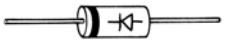
BUILD A ZENER DIODE 5-VOLT INDICATOR

YOU WILL BUILD A SIMPLE CIRCUIT THAT CAUSES AN LED TO GLOW ONLY WHEN THE INPUT VOLTAGE IS AT OR ABOVE 5 VOLTS PLUS THE LED VOLTAGE (ABOUT 2 VOLTS).

PARTS YOU WILL NEED



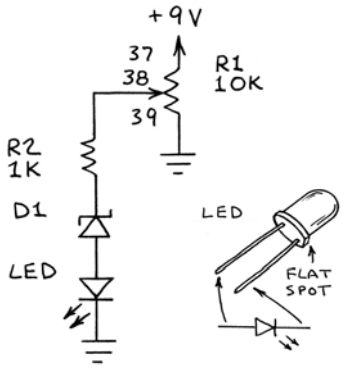
R2-1K (BRN-BLK-RED)



D1-5-VOLT ZENER DIODE

LED 1-RED LED

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS P13 AND P16.
3. ☐ INSERT D1 ACROSS P18 (CATHODE) AND T18 (ANODE).
4. ☐ INSERT LED ACROSS T20 (ANODE) AND GROUND (CATHODE).
5. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
6. ☐ CONNECT SPRING 38 TO P11 (BLU WIRE).
7. ☐ CONNECT SPRING 37 TO V6 (+9V) (BLU WIRE).

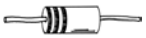
2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. ROTATE THE KNOB OF THE 10K CONSOLE POT (R1) ALL THE WAY TO THE LEFT (COUNTERCLOCKWISE). THEN PRESS THE POWER SWITCH TO ON. THE LED WILL NOT BE GLOWING AT THIS POINT. NOW ROTATE R1'S KNOB TO THE RIGHT. R1 FORMS A VOLTAGE DIVIDER. EVENTUALLY THE LED WILL BEGIN TO GLOW AS THE VOLTAGE FROM THE VOLTAGE DIVIDER REACHES, AND THEN EXCEEDS, THE ZENER BREAKDOWN VOLTAGE OF D1. CAN YOU THINK OF ANY PRACTICAL APPLICATIONS FOR A CIRCUIT LIKE THIS?

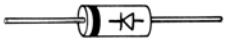
BUILD A ZENER DIODE VOLTAGE REGULATOR DEMONSTRATION CIRCUIT

THE EASIEST WAY TO UNDERSTAND HOW A ZENER DIODE IS USED TO REGULATE VOLTAGES IS TO BUILD A SIMPLE DEMONSTRATION REGULATOR CIRCUIT WITH VARIOUS INPUT VOLTAGES. YOU WILL BUILD A CIRCUIT THAT PROVIDES FOUR DIFFERENT INPUT VOLTAGES TO A ZENER DIODE REGULATOR. YOU WILL PRESS PUSHBUTTON SWITCHES TO SELECT VARIOUS INPUT VOLTAGES WHILE WATCHING THE OUTPUT VOLTAGE ON THE METER. YOU WILL FIND THAT THE ZENER REGULATOR GOES TO WORK WHENEVER THE INPUT VOLTAGE MATCHES OR EXCEEDS THE BREAKDOWN VOLTAGE OF THE ZENER DIODE.

PARTS YOU WILL NEED



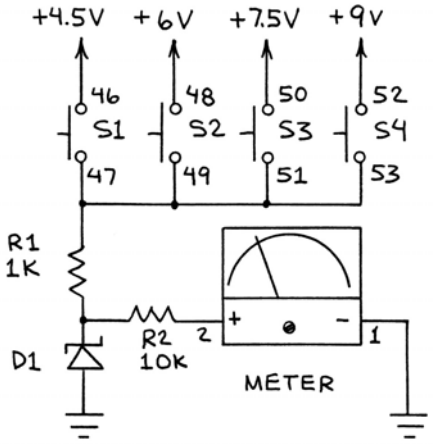
R1-1K (BRN-BLK-RED)
R2-10K (BRN-BLK-ORG)



D1-5-VOLT ZENER DIODE

ONE ZENER DIODE IS PROVIDED WITH YOUR LEARNING LAB. IT RESEMBLES THE SILICON DIODES BUT HAS DIFFERENT MARKINGS. LOOK FOR THE NUMBER 5 ON THE SIDE OF THE CASE.

CIRCUIT DIAGRAM



R2 CONVERTS THE 0-1 MA METER TO A VOLTMETER (0.1 MA = 1 VOLT).

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS P13 AND P16.
3. ☐ INSERT R2 ACROSS P20 AND P22.
4. ☐ INSERT D1 ACROSS P18 (CATHODE) AND GROUND (ANODE).
5. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
6. ☐ CONNECT SPRING 2 TO P25 (BLU WIRE).
7. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
8. ☐ CONNECT SPRINGS 49 AND 51 (WHT WIRE).
9. ☐ CONNECT SPRINGS 51 AND 53 (WHT WIRE).
10. ☐ CONNECT SPRING 47 TO P11 (RED WIRE).
11. ☐ CONNECT SPRING 46 TO V3 (+4.5V) (BLU WIRE).
12. ☐ CONNECT SPRING 48 TO V4 (+6V) (BLU WIRE).
13. ☐ CONNECT SPRING 50 TO V5 (+7.5V) (BLU WIRE).
14. ☐ CONNECT SPRING 52 TO V6 (+9V) (BLU WIRE).

2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. BE SURE R2 IS 10K SINCE TOO LITTLE RESISTANCE MAY CAUSE THE METER TO BE DAMAGED. PUSH THE POWER SWITCH ON. THE METER WILL INDICATE ABOUT 0 MA (0 VOLT).

PRESSING SWITCHES S1-S4 APPLIES FOUR DIFFERENT INPUT VOLTAGES TO THE CIRCUIT. THE TABLE SHOWS THE OUTPUT VOLTAGE INDICATED BY THE METER WHEN SWITCHES S1-S4 ARE PRESSED. S1 APPLIES AN INPUT VOLTAGE LESS THAN THE 5-VOLT ZENER VOLTAGE OF D1. S2, S3 AND S4 APPLY INPUT VOLTAGES GREATER THAN THE ZENER VOLTAGE. YET IN THESE CASES THE METER INDICATES A STEADY OUTPUT OF 5 VOLTS, THE ZENER BREAKDOWN VOLTAGE OF D1.

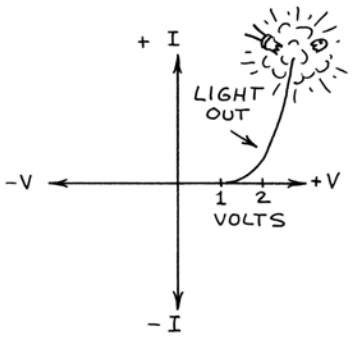
INPUT SWITCH	INPUT VOLTAGE	OUTPUT VOLTAGE
S1	4.5	3.8
S2	6	5.0
S3	7.5	5.0
S4	9	5.0

THE VOLTAGES IN THE TABLE ARE APPROXIMATE. THE ACTUAL VOLTAGES THAT YOU MEASURE DEPEND ON THE FRESHNESS OF THE BATTERIES IN YOUR LEARNING LAB. IF PRESSING S2 GIVES AN OUTPUT BELOW 5 VOLTS (0.5 MA ON THE METER), THEN THE LEARNING LAB BATTERIES ARE WEAK.

LIGHT-EMITTING DIODES (LEDS) AND HOW TO USE THEM

THE BEST KNOWN OF ALL DIODES ARE THOSE THAT HAVE THE ALMOST MAGICAL ABILITY TO EMIT LIGHT. LIGHT-EMITTING DIODES (LEDS) ARE AVAILABLE THAT EMIT ALL THE COLORS OF THE VISIBLE SPECTRUM FROM BLUE TO RED. WHITE LEDS ARE BLUE LEDS WITH A SPECIAL PHOSPHOR THAT GLOWS WHITE. LEDS HAVE MANY USES AS INDICATORS AND DISPLAYS AND IN COMMUNICATIONS. SOME LEDS EMIT INVISIBLE NEAR-INFRARED. THESE LEDS ARE USED IN REMOTE CONTROLS FOR TV SETS AND TO LINK COMPUTERS WITH OTHER COMPUTERS. YOUR ELECTRONICS LEARNING LAB CONSOLE FEATURES A 7-SEGMENT LED DISPLAY AND 10 LED INDICATORS. A RED AND A GREEN LED ARE INCLUDED WITH THE LOOSE PARTS.

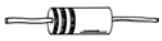
THE GRAPH SHOWS HOW A LIGHT-EMITTING DIODE CONDUCTS MUCH LIKE A STANDARD DIODE. SILICON DIODES TURN ON AT ABOUT 0.6 VOLT. LEDS REQUIRE HIGHER VOLTAGES, RANGING FROM AROUND 1.5 VOLTS FOR NEAR-INFRARED LEDS TO SEVERAL VOLTS FOR BLUE LEDS. ALWAYS OPERATE LEDS WITHIN THEIR SPECIFICATIONS. TOO MUCH CURRENT WILL OVERHEAT AND EVEN DESTROY AN LED. IT'S USUALLY NECESSARY TO LIMIT THE CURRENT TO AN LED WITH A SERIES RESISTOR BETWEEN THE LED AND THE CIRCUIT. THE LEDS ON YOUR LEARNING LAB CONSOLE HAVE BUILT-IN SERIES RESISTORS.



BUILD A BASIC LED DRIVER CIRCUIT

AN LED MUST NOT BE CONNECTED DIRECTLY ACROSS A POWER SOURCE. YOU WILL BUILD A BASIC LED DRIVER THAT USES A SERIES RESISTOR TO LIMIT CURRENT TO A SAFE VALUE.

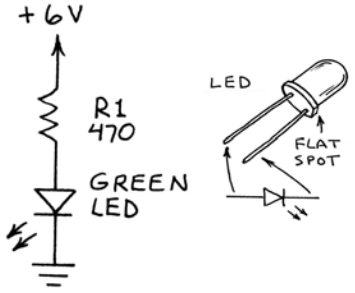
PARTS YOU WILL NEED



R1-470 (YEL-VIO-BRN)

LED 1-GREEN LED

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS E20 AND V4 (+6V).
3. ☐ INSERT THE LED ACROSS E16 (ANODE) AND H16 (CATHODE).
4. ☐ CONNECT H20 TO GROUND (RED WIRE).

2. TEST THE CIRCUIT

PUSH THE POWER SWITCH TO ON. THE LED SHOULD GLOW BRIGHTLY WITH A PURE GREEN COLOR. IF IT DOES NOT, CHECK TO MAKE SURE YOU INSTALLED THE LED IN THE CORRECT DIRECTION. THE CATHODE LEAD IS INDICATED BY A FLAT SPOT ON THE BASE OF THE LED. THE COLOR EMITTED BY THE GREEN LED CLOSELY MATCHES THE PEAK SENSITIVITY OF THE HUMAN EYE.

GOING FURTHER

YOU CAN DETERMINE THE RESISTANCE OF THE CURRENT-LIMITING SERIES RESISTOR REQUIRED TO ALLOW A SPECIFIC CURRENT THROUGH AN LED. THE FORMULA IS:

$$R = [V(IN) - V(LED)] / I(LED)$$

THE FORMULA CAN BE REARRANGED TO FIND THE CURRENT WHEN R IS ALREADY PRESENT, AS IN THIS CIRCUIT:

$$I(LED) = [V(IN) - V(LED)] / R$$

LET'S APPLY THE FORMULA TO THIS CIRCUIT TO FIND THE CURRENT THROUGH THE GREEN LED. V (LED) FOR A GREEN LED IS USUALLY AROUND 2 VOLTS. THEREFORE:

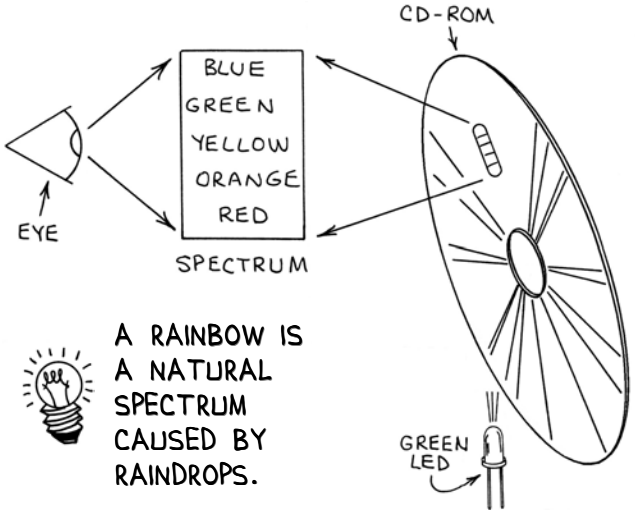
$$I(LED) = (6 - 2) / 470$$
$$= 0.0085 \text{ AMPS OR}$$
$$= 8.5 \text{ MILLIAMPS (MA)}$$

SINCE THE LED CAN TOLERATE 20-30 MA, R1 PROVIDES MORE THAN ADEQUATE CURRENT LIMITING.

EXAMINE THE SPECTRUM OF A GREEN LED

TODAY'S LIGHT-EMITTING DIODES ARE THE END RESULT OF MARVELOUS TECHNOLOGICAL ADVANCES. A MAJOR PROBLEM IN MAKING LEDS IS TO ACHIEVE THE PROPER COLOR BALANCE. GREEN, YELLOW AND ORANGE LEDS ARE ESPECIALLY DIFFICULT TO DESIGN, BECAUSE THESE COLORS ARE VERY NARROW SLICES OF THE SPECTRUM THAT WE SEE AS VISIBLE LIGHT. HERE YOU WILL EXAMINE THE SPECTRUM OF A GREEN LED TO SEE THAT IT ALSO INCLUDES COLORS ON EITHER SIDE OF THE GREEN SPECTRUM.

1. PREPARE THE EXPERIMENT



A RAINBOW IS A NATURAL SPECTRUM CAUSED BY RAINDROPS.

YOU WILL NEED A CD-ROM OR OTHER KIND OF LASER DISC FOR THIS EXPERIMENT. REMOVE THE CD-ROM FROM ITS PROTECTIVE BOX OR COVER AND ALLOW BRIGHT WHITE LIGHT TO SHINE ON THE DISC. NOTICE THE RAINBOW OF COLORS REFLECTED FROM THE SHINY SURFACE OF THE DISC. THE RAINBOWS OF LIGHT ARE THE SPECTRUM OF COLORS CONTAINED WITHIN THE WHITE LIGHT. SINCE THE DATA-STORING PITS IN THE LASER DISC ARE THE SAME SIZE AS A WAVLENGTH OF RED LIGHT, THEY HAVE THE ABILITY TO BREAK WHITE LIGHT INTO ITS CONSTITUENT COLORS. THE PROCESS IS KNOWN AS <u>DIFFRACTION</u>.

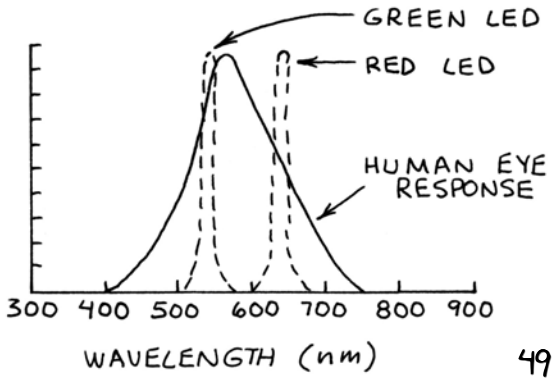
PREPARE THE LED EXPERIMENT BY BUILDING THE SIMPLE GREEN LED CIRCUIT ON THE PREVIOUS PAGE. YOU CAN USE A LOWER RESISTANCE FOR R1 TO INCREASE THE BRIGHTNESS OF THE LED. FOR EXAMPLE, 220 OHMS WILL GIVE A CURRENT OF AROUND 20 MA. (USE THE FORMULAS TO DETERMINE HOW THIS NUMBER WAS DETERMINED.) YOU CAN ALSO INCREASE THE VOLTAGE TO INCREASE THE BRIGHTNESS. BUT YOU MUST FIRST USE THE PROPER FORMULA TO MAKE SURE THE CURRENT DOES NOT EXCEED 30 MA.

2. DO THE EXPERIMENT

WITH THE ROOM LIGHTS DIMMED, LEAN THE CD-ROM OVER THE LED AS SHOWN ABOVE. YOU WILL SEE THE REFLECTED GREEN GLOW FROM THE LED IN THE SHINY SURFACE OF THE DISK. LOOK ABOVE OR OFF TO ONE SIDE AND YOU WILL SEE A SHORT LITTLE RAINBOW. THIS IS THE SPECTRUM OF THE LIGHT FROM THE LED. LOOK VERY CAREFULLY. YOU WILL SEE THAT THE SPECTRUM FROM THE GREEN LED REACHES THE BLUE-GREEN ON ONE END AND THE ORANGE-RED ON THE OPPOSITE END. THOUGH THESE COLORS ARE FAINT, THEY MUST BE TAKEN INTO ACCOUNT WHEN GREEN LEDS ARE DESIGNED.

MORE ABOUT LED COLORS

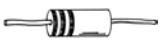
THE SOLID CURVE IN THE GRAPH IS THE RESPONSE OF THE HUMAN EYE TO THE COLORS OF THE SPECTRUM. THE FIRST NARROW, DASHED CURVE IS THE EMISSION OF A GREEN LED LIKE THE ONE PROVIDED WITH YOUR ELECTRONICS LEARNING LAB. THE SECOND NARROW DASHED CURVE IS THE EMISSION OF A RED LED LIKE THOSE IN YOUR LEARNING LAB. SINCE THE GREEN LED CLOSELY MATCHES THE PEAK OF HUMAN VISION, LESS POWER IS REQUIRED FOR A GREEN LED TO APPEAR AS BRIGHT AS A RED LED.



LED REVERSE POLARITY INDICATOR

SINCE LEDS EMIT LIGHT ONLY WHEN CONNECTED IN THE PROPER DIRECTION, THEY ARE VERY SIMPLE POLARITY INDICATORS. YOU WILL USE A RED LED, AND A GREEN LED CONNECTED IN REVERSE-PARALLEL, TO BUILD A POLARITY INDICATOR CIRCUIT.

PARTS YOU WILL NEED

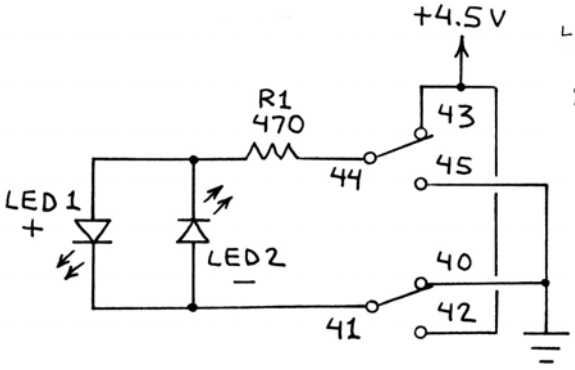


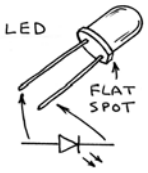
R1-470 OHMS (YEL-VIO-BRN)

LED 1--GREEN LED

LED 2-RED LED

CIRCUIT DIAGRAM





WHAT IS POLARITY?

IN ELECTRONICS, POLARITY REFERS TO THE DIRECTION OF CURRENT FLOW AND TO THE POSITIVE AND NEGATIVE STATES IN A CIRCUIT. THE TWO TERMINALS OF A BATTERY ARE POLARIZED SINCE ONE IS AT A POSITIVE STATE WITH RESPECT TO THE OTHER. ELECTROLYTIC CAPACITORS AND LEDS ARE POLARIZED, WHICH MEANS THEY MUST BE CONNECTED IN A CIRCUIT IN A SPECIFIC DIRECTION.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT LED 1 ACROSS K11 (ANODE) AND H11 (CATHODE).
3. ☐ INSERT LED 2 ACROSS H15 (ANODE) AND K15 (CATHODE).
4. ☐ INSERT R1 ACROSS K13 AND T13.
5. ☐ CONNECT SPRINGS 42 AND 43 (WHT WIRE).
6. ☐ CONNECT SPRINGS 40 AND 45 (WHT WIRE).
7. ☐ CONNECT SPRING 41 TO H13 (BLU WIRE).
8. ☐ CONNECT SPRING 44 TO T11 (RED WIRE).
9. ☐ CONNECT SPRING 40 TO GROUND (WHT WIRE).
10. ☐ CONNECT SPRING 43 TO V3 (+4.5V) (BLU WIRE).

2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. THEN PUSH THE POWER SWITCH ON. WHEN THE DPDT SWITCH IS PUSHED UP, ONLY THE GREEN LED GLOWS. WHEN THE DPDT SWITCH IS PUSHED DOWN, ONLY THE RED LED GLOWS. R1 LIMITS CURRENT TO A SAFE VALUE.

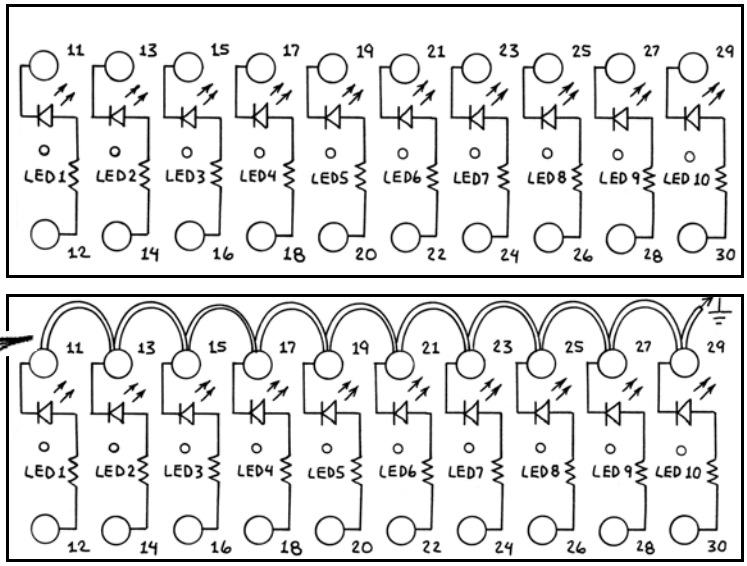
THE OPERATION OF THIS CIRCUIT IS EASY TO ANALYZE. REFER TO THE CIRCUIT DIAGRAM ABOVE AND NOTICE THAT THE DPDT SWITCH IS ARRANGED LIKE THE ONE INSTALLED IN YOUR LEARNING LAB CONSOLE, WITH THE UP POSITION CLOSEST TO SPRINGS 40 AND 43. THE CIRCUIT DIAGRAM SHOWS THE CONNECTION INSIDE THE SWITCH WHEN THE SWITCH HANDLE IS PUSHED UP. THE DIODE SYMBOL POINTS IN THE DIRECTION OF CURRENT FLOW. WHEN THE SWITCH IS POSITIONED AS IN THE CIRCUIT DIAGRAM, CURRENT CAN FLOW ONLY THROUGH LED 1, THE GREEN LED. WHEN THE DPDT SWITCH IS PUSHED DOWN, CURRENT CAN FLOW ONLY THROUGH LED 2, THE RED LED.

GOING FURTHER

USE THE LED FORMULAS (PAGE 48) TO CALCULATE THE CURRENT THROUGH LED 1 AND LED 2. ASSUME V (LED) IS 2.0 VOLTS FOR THE GREEN LED AND 1.7 VOLTS FOR THE RED LED.

THE CONSOLE LEDS AND HOW TO USE THEM

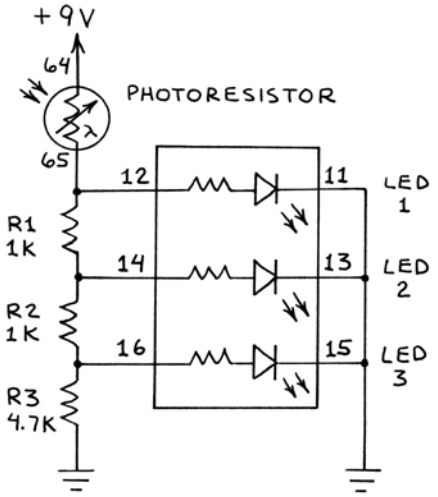
YOUR ELECTRONICS LEARNING LAB CONSOLE INCLUDES A VERY HANDY ROW OF TEN LEDS, COMPLETE WITH PREINSTALLED SERIES RESISTORS TO LIMIT CURRENT. YOU WILL USE THESE LEDS IN MANY PROJECTS. WHEN MORE THAN ONE LED IS USED, ALL THE CATHODE LEADS GO TO GROUND. YOU CAN SAVE STEPS BY WIRING THE CATHODE SPRINGS TOGETHER WITH WHITE WIRES, AS SHOWN HERE, OR WITH A SINGLE BLUE WIRE FROM WHICH YOU HAVE REMOVED THE INSULATION. CONNECT SPRING 29 TO GROUND (BLUE WIRE).



USE THE CONSLE LEDS TO MAKE A SIMPLE LED BARGRAPH LIGHT METER

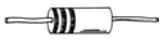
YOU WILL USE THE PHOTORESISTOR AND THREE OF THE CONSOLE LEDS TO MAKE AN ULTRA-SIMPLE BARGRAPH LIGHT METER. WHEN THE PHOTORESISTOR IS DARK, NO LEDS WILL GLOW. WHEN THE PHOTORESISTOR IS ILLUMINATED, THE THREE LEDS WILL GLOW IN SEQUENCE AS THE LIGHT IS INCREASED TO INDICATE THE LEVEL OF BRIGHTNESS.

CIRCUIT DIAGRAM



THE PHOTORESISTOR AND RESISTORS R1-R3 FORM A VOLTAGE DIVIDER.

PARTS YOU WILL NEED



R1, R2-1K (BRN-BLK-RED)
R3-4.7K (YEL-V10-RED)

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT R1 ACROSS L5 AND L6.
3. ☐ INSERT R2 ACROSS L10 AND L11.
4. ☐ INSERT R3 ACROSS L15 AND GROUND.
5. ☐ CONNECT SPRING 12 TO L1 (RED WIRE).
6. ☐ CONNECT SPRING 14 TO L8 (RED WIRE).
7. ☐ CONNECT SPRING 16 TO L13 (RED WIRE).
8. ☐ CONNECT SPRING 65 TO L2 (YEL WIRE).
9. ☐ CONNECT SPRINGS 11 AND 13 (WHT WIRE).
10. ☐ CONNECT SPRINGS 13 AND 15 (WHT WIRE).
11. ☐ CONNECT SPRING 15 TO GROUND (BLU WIRE).
12. ☐ CONNECT SPRING 64 TO V6 (+9V) (BLU WIRE).

2. TEST THE CIRCUIT

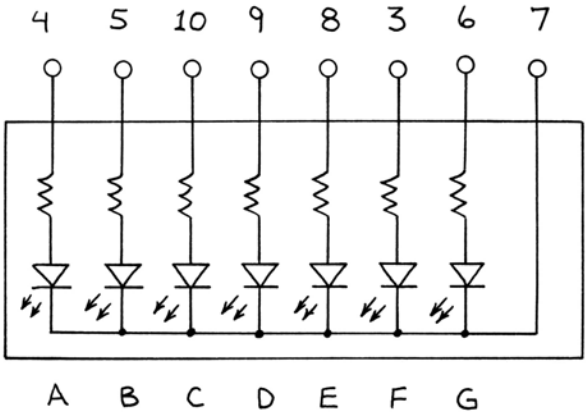
CHECK YOUR WIRING FOR ERRORS AND THEN PUSH THE POWER SWITCH ON. PLACE A FINGER OR DARK OBJECT OVER THE PHOTORESISTOR TO KEEP LIGHT FROM STRIKING IT. ALL THE LEDS SHOULD BE OFF. THEN SLOWLY ALLOW LIGHT TO REACH THE PHOTORESISTOR. THE LEDS WILL GLOW IN SEQUENCE WHEN THE VOLTAGE APPLIED TO THEM REACHES THEIR TURN-ON LEVEL. SLOWLY BLOCK THE LIGHT AGAIN, AND THEY WILL TURN OFF IN REVERSE ORDER. LATER YOU WILL BUILD A MUCH FANCIER BARGRAPH LIGHT METER THAT USES ALL 10 LEDS ON THE CONSOLE AND A DIGITAL LOGIC CIRCUIT.

THE CONSOLE LED DIGITAL DISPLAY AND HOW TO USE IT

YOUR LEARNING LAB INCLUDES A 7-SEGMENT LED DISPLAY SIMILAR TO DISPLAYS USED IN MANY DIGITAL CLOCKS, WATCHES AND CALCULATORS. EACH DISPLAY SEGMENT IS AN INDEPENDENT LED. BY SELECTING WHICH SEGMENTS ARE ILLUMINATED, ALL 10 DIGITS CAN BE REPRESENTED:

0 1 2 3 4 5 6 7 8 9

HOW THE LEDS IN THE 7-SEGMENT DISPLAY ARE CONNECTED

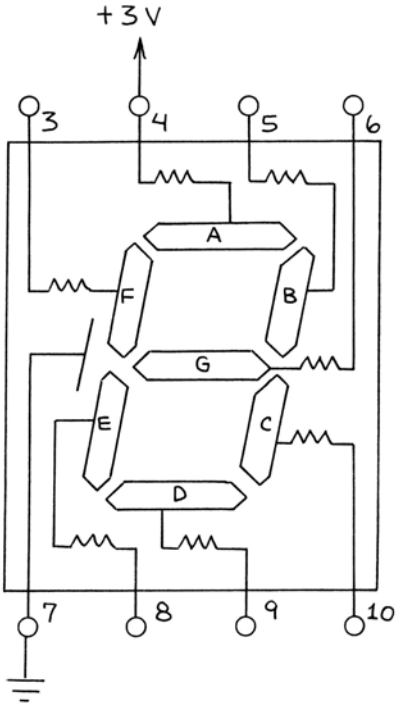


THIS DIAGRAM SHOWS HOW THE SEVEN LEDS ARE CONNECTED INSIDE THE 7-SEGMENT DISPLAY. THE NUMBERS ALONG THE TOP ARE THE CONNECTION SPRINGS ON THE CONSOLE. THE LETTERS ALONG THE BOTTOM REFER TO THE SEGMENT OF THE DISPLAY REPRESENTED BY EACH LED (SEE DIAGRAM BELOW). EACH LED HAS ITS OWN SERIES RESISTOR TO LIMIT CURRENT. THE SERIES RESISTORS ARE INSTALLED ON A SMALL CIRCUIT BOARD BEHIND THE LED DISPLAY. SINCE THE LED CATHODES ARE CONNECTED TOGETHER (IN COMMON), THIS IS KNOWN AS A COMMON CATHODE DISPLAY.

USE ONE SEGMENT IN THE 7-SEGMENT DISPLAY AS A "POWER ON" INDICATOR

YOU WILL GET ACQUAINTED WITH THE 7-SEGMENT DISPLAY BY USING ONE SEGMENT AS A "POWER ON" INDICATOR FOR YOUR LEARNING LAB.

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRING 7 TO GROUND (BLU WIRE).
3. ☐ CONNECT SPRING 4 TO V2 (+3V) (RED WIRE).

2. TEST THE CIRCUIT

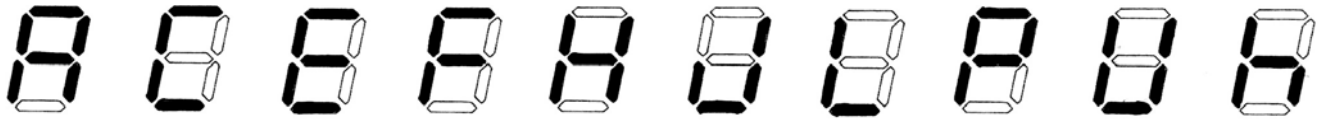
CHECK YOUR WIRING FOR ERRORS. PUSH THE POWER SWITCH ON, AND THE UPPERMOST SEGMENT OF THE DISPLAY WILL GLOW RED. YOU CAN LEAVE THIS LED POWER INDICATOR IN PLACE UNTIL YOU BUILD PROJECTS THAT USE ALL THE SEGMENTS IN THE DISPLAY. OR YOU CAN USE ONE OF THE TEN CONSOLE LEDS FOR THE SAME PURPOSE. EACH OF THESE LEDS HAS A BUILT-IN SERIES RESISTOR.

IMPORTANT REMINDER

THE LED DISPLAY AND CONSOLE LEDS HAVE BUILT-IN SERIES RESISTORS, BUT THE LOOSE LEDS PROVIDED WITH YOUR LEARNING LAB DO NOT. KEEP THIS IN MIND WHEN YOU USE THEM IN CIRCUITS.

USE THE 7-SEGMENT LED READOUT TO GENERATE SYMBOLS AND CHARACTERS

WHILE 7-SEGMENT DISPLAYS ARE USUALLY USED TO FORM NUMBERS, VARIOUS SYMBOLS AND LETTERS OF THE ALPHABET CAN ALSO BE DISPLAYED . HERE ARE NINE UPPER CASE LETTERS AND ONE LOWER CASE LETTER:

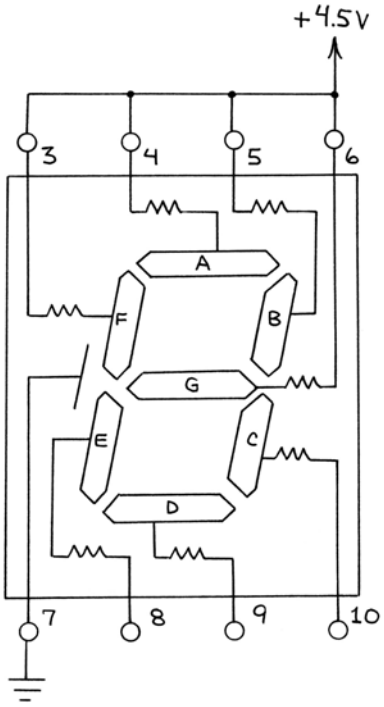


A C E F H J L P U H

USE FOUR SEGMENTS IN THE 7-SEGMENT DISPLAY TO MAKE A SYMBOL

YOU WILL CONNECT FOUR ANODES OF THE 7-SEGMENT DISPLAY TO +4.5 VOLTS TO FORM A SMALL SQUARE.

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

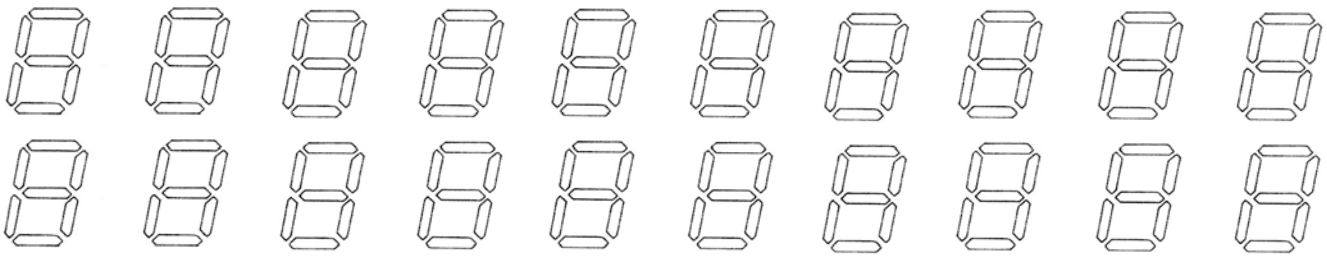
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ CONNECT SPRING 7 TO GROUND (BLU WIRE).
3. ☐ CONNECT SPRINGS 3 AND 4 (WHT WIRE).
4. ☐ CONNECT SPRINGS 4 AND 5 (WHT WIRE).
5. ☐ CONNECT SPRINGS 5 AND 6 (WHT WIRE).
6. ☐ CONNECT SPRING 6 TO V2 (+4.5V) (RED WIRE).

2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. PUSH THE POWER SWITCH ON, AND THE FOUR UPPERMOST SEGMENTS OF THE DISPLAY WILL FORM A SMALL GLOWING SQUARE. THE SEGMENTS ARE BRIGHTER THAN IN THE PREVIOUS CIRCUIT SINCE THE VOLTAGE IS HIGHER. NO EXTERNAL CURRENT LIMITING RESISTORS ARE NEEDED SINCE THE 7-SEGMENT DISPLAY HAS ITS OWN SET OF RESISTORS.

GOING FURTHER

THE INTEGRATED CIRCUITS SUPPLIED WITH YOUR LEARNING LAB INCLUDE A 4511 7-SEGMENT DECODER DRIVER. THIS CHIP IS DESIGNED SPECIFICALLY TO PRODUCE NUMBERS ON THE DISPLAY. YOU WILL BUILD CIRCUITS USING THIS IC LATER. FOR NOW, EXPLORE OTHER APPLICATIONS FOR THE DISPLAY BY FINDING OUT HOW MANY SYMBOLS AND CHARACTERS YOU CAN DESIGN USING THESE BLANK 7-SEGMENT OUTLINES:



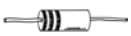
TRANSISTORS AND HOW TO USE THEM

NPN AND PNP TRANSISTORS ARE USED AS SWITCHES AND AMPLIFIERS. THEY ARE ALSO USED IN CIRCUITS THAT CYCLE BETWEEN TWO STATES (LIKE OSCILLATORS AND MULTIVIBRATORS). PNP AND NPN TRANSISTORS HAVE THREE LEADS, THE EMITTER, BASE AND COLLECTOR. NORMALLY CURRENT DOES NOT FLOW BETWEEN THE EMITTER AND COLLECTOR. A SMALL CURRENT AT THE BASE ALLOWS A MUCH LARGER CURRENT TO FLOW BETWEEN THE EMITTER AND COLLECTOR.

BUILD A SIMPLE NPN TRANSISTOR SWITCHING CIRCUIT

YOU WILL USE AN NPN TRANSISTOR AS A SWITCH THAT CONTROLS THE CURRENT TO AN LED.

PARTS YOU WILL NEED

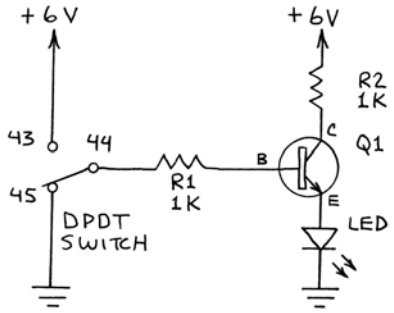


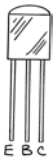
R1, R2-1K (BRN-BLK-RED)

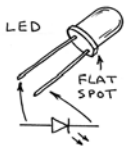
Q1-9014 NPN TRANSISTOR

LED-RED LED

CIRCUIT DIAGRAM







1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT L13 (E), J13 (B) AND H13 (C).
3. ☐ INSERT R1 ACROSS J5 AND J11.
4. ☐ INSERT R2 ACROSS H15 AND V4 (+6V).
5. ☐ INSERT LED ACROSS T11 (ANODE) AND GROUND (CATHODE).
6. ☐ CONNECT L11 AND T13 (WHT WIRE).
7. ☐ CONNECT SPRING 43 TO V4 (+6V) (BLU WIRE).
8. ☐ CONNECT SPRING 44 TO J1 (RED WIRE).
9. ☐ CONNECT SPRING 45 TO GROUND (RED WIRE).

2. TEST THE CIRCUIT

PUSH THE DPDT SWITCH DOWN AND THE POWER SWITCH ON. THE LED WILL BE OFF. PUSH THE DPDT SWITCH UP, AND Q1 WILL SWITCH ON. CURRENT WILL THEN FLOW FROM THE COLLECTOR TO THE EMITTER OF Q1, AND THE LED WILL GLOW. R2 LIMITS THE LED CURRENT.

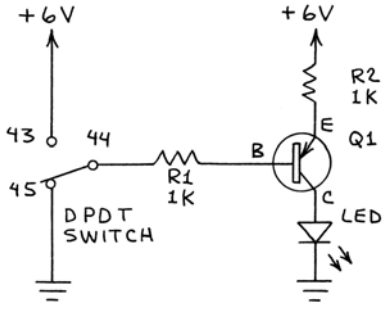
BUILD A SIMPLE PNP TRANSISTOR SWITCHING CIRCUIT

YOU WILL USE A PNP TRANSISTOR AS A SWITCH THAT CONTROLS THE CURRENT TO AN LED.

PARTS YOU WILL NEED

Q1-9015 PNP TRANSISTOR

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

MODIFY THE CIRCUIT ABOVE:

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE Q1 AND REPLACE WITH PNP Q1.

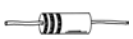
2. TEST THE CIRCUIT

PUSH THE POWER SWITCH ON AND THE DPDT SWITCH DOWN. THE LED WILL GLOW BECAUSE THE PNP TRANSISTOR IS SWITCHED ON WHEN ITS BASE IS AT GROUND. IN THE CIRCUIT ABOVE, THE NPN TRANSISTOR IS SWITCHED ON WHEN ITS BASE IS AT +6 VOLTS. PUSH THE DPDT SWITCH UP. Q1 AND THE LED WILL TURN OFF.

BUILD AN NPN TRANSISTOR CIRCUIT THAT CAN BE ADJUSTED TO BE PARTIALLY ON

IN THE PREVIOUS TWO CIRCUITS A TRANSISTOR IS USED AS A SWITCH THAT IS FULLY ON OR FULLY OFF. AMPLIFIERS REQUIRE TRANSISTORS THAT ARE PARTIALLY ON. YOU WILL BUILD A SIMPLE CIRCUIT THAT DEMONSTRATES HOW A TRANSISTOR CAN BE PARTIALLY ON.

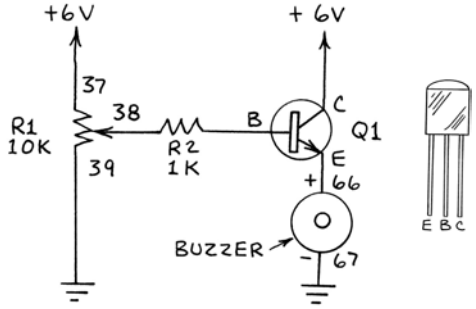
PARTS YOU WILL NEED



R2-1K (BRN-BLK-RED)

Q1-9014 NPN TRANSISTOR

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT L13 (E), J13 (B) AND H13 (C).
3. ☐ INSERT R2 ACROSS J5 AND J11.
4. ☐ CONNECT SPRING 37 TO V4 (+6V) (BLU WIRE).
5. ☐ CONNECT SPRING 38 TO J1 (RED WIRE).
6. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
7. ☐ CONNECT SPRING 66 TO L15 (BLU WIRE).
8. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).
9. ☐ CONNECT H15 TO V4 (+6V) (WHT WIRE).

TIP: REPLACE BUZZER WITH CONSOLE LED 10. (USE BLUE WIRES. CONNECT SPRING 29 TO GROUND AND SPRING 30 TO L15). THE LED WILL BRIGHTEN AS YOU ADJUST CONSOLE POT R1.

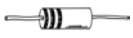
2. TEST THE CIRCUIT

ROTATE THE KNOB ON THE 10K CONSOLE POT (R1) FULLY TO THE LEFT (COUNTERCLOCKWISE). PUSH THE POWER SWITCH ON AND SLOWLY ROTATE R1'S KNOB CLOCKWISE. YOU WILL SOON HEAR A HIGH-PITCHED TONE FROM THE BUZZER. AS YOU CONTINUE TO ROTATE R1'S KNOB, EVENTUALLY THE BUZZER WILL RECEIVE FULL CURRENT AND WILL EMIT SOUND AT FULL VOLUME.

DRIVE A RELAY WITH A TRANSISTOR

YOU WILL USE AN NPN TRANSISTOR AS A SWITCH THAT DRIVES A RELAY.

PARTS YOU WILL NEED

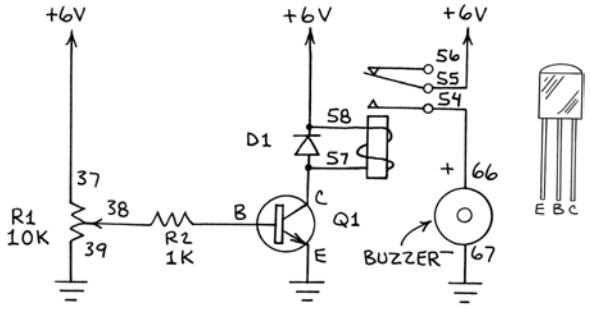


R2-1K (BRN-BLK-RED)

D1-1N4148

Q1-9014 NPN

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT L13 (E), J13 (B) AND H13 (C).
3. ☐ INSERT R2 ACROSS J5 AND J11.
4. ☐ CONNECT D1 ACROSS SPRINGS 58 (CATHODE) AND 57 (ANODE).
5. ☐ CONNECT L15 TO GROUND (WHT WIRE).
6. ☐ CONNECT SPRING 57 TO H15 (BLU WIRE).
7. ☐ CONNECT SPRINGS 54 AND 66 (RED WIRE).
8. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).
9. ☐ CONNECT SPRINGS 55 AND 58 (WHT WIRE).
10. ☐ CONNECT SPRING 37 TO V4 (+6V) (BLU WIRE).
11. ☐ CONNECT SPRING 38 TO J1 (RED WIRE).
12. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
13. ☐ CONNECT SPRING 58 TO V4 (+6V) (BLU WIRE).

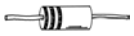
2. TEST THE CIRCUIT

ROTATE THE KNOB ON THE 10K CONSOLE POT (R1) FULLY TO THE LEFT. PUSH THE POWER SWITCH ON AND ROTATE R1'S KNOB TO THE RIGHT. SUDDENLY THE BUZZER WILL SOUND OFF AS THE RELAY PULLS IN. THIS CIRCUIT SHOWS HOW A TRANSISTOR CAN DRIVE A RELAY WHICH CAN SWITCH MORE CURRENT THAN A TRANSISTOR ALONE.

BUILD A SIMPLE TWO-TRANSISTOR OSCILLATOR

SUPPOSE YOU CONNECT THE BASE LEAD OF A TRANSISTOR TO A CAPACITOR WHICH IS BEING CHARGED TO A VOLTAGE THROUGH A RESISTOR. THE TRANSISTOR WILL EVENTUALLY SWITCH ON WHEN THE CHARGE ON THE CAPACITOR REACHES THE TRANSISTOR'S TURN-ON VOLTAGE. IF THE CAPACITOR CAN NOW DISCHARGE THROUGH THE TRANSISTOR, THE TRANSISTOR WILL SWITCH ITSELF OFF WHEN THE CHARGE ON C1 FALLS BELOW THE TRANSISTOR'S TURN-ON VOLTAGE. YOU NOW HAVE A VERY USEFUL OSCILLATOR CIRCUIT THAT WILL CONTINUOUSLY SWITCH ITSELF OFF AND ON. YOU WILL BUILD A TWO-TRANSISTOR OSCILLATOR BASED ON THIS PRINCIPLE.

PARTS YOU WILL NEED

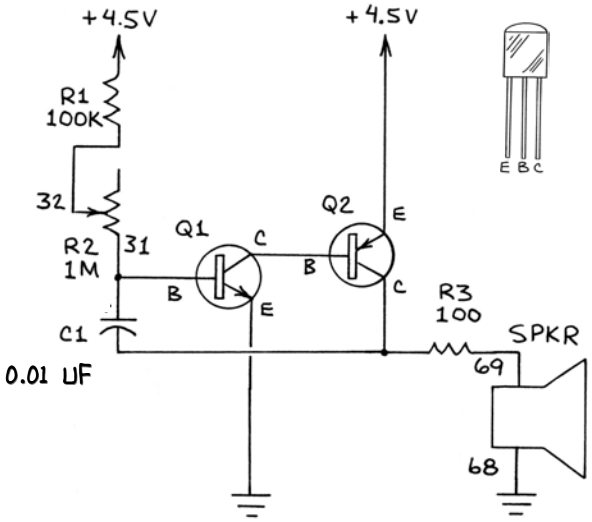


R1-100K (BRN-BLK-YEL)
R3-100 OHMS (BRN-BLK-BRN)

C1-0.01 UF CAPACITOR (103)

Q1-9014 NPN TRANSISTOR
Q2-9015 PNP TRANSISTOR

CIRCUIT DIAGRAM



HOW THE CIRCUIT WORKS.

C1 CHARGES THROUGH R1 AND R2 UNTIL THE CHARGE ON C1 IS HIGH ENOUGH TO TURN ON Q1. THIS CAUSES Q2 TO SWITCH ON. THE SPEAKER IS NOW CONNECTED TO +4.5 VOLTS THROUGH Q2 AND R3, SO IT EMITS A "POP." MEANWHILE, C1 DISCHARGES THROUGH THE BASE-EMITTER OF Q1. THIS CAUSES Q1 TO SWITCH OFF, WHICH THEN SWITCHES Q2 OFF. THE CYCLE THEN REPEATS. IF R2 IS ADJUSTED TO SPEED UP THE CHARGING OF C1, AS IN THIS CIRCUIT, THE POPS FROM THE SPEAKER WILL MERGE INTO A CONTINUOUS BUZZ OR TONE. WHILE THE CIRCUIT WILL WORK WITHOUT IT, R3 PROTECTS Q2 AND THE SPEAKER FROM EXCESSIVE CURRENT WHILE KEEPING THE VOLUME AT A REASONABLE LEVEL.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT L13 (E), J13 (B) AND H13 (C).
3. ☐ INSERT Q2 AT L18 (E), J18 (B) AND H18 (C).
4. ☐ CONNECT R1 ACROSS SPRING 32 AND F1.
5. ☐ CONNECT F5 TO V3 (+4.5V) (WHT WIRE).
6. ☐ CONNECT SPRING 31 TO J11 (RED WIRE).
7. ☐ INSERT C1 ACROSS J15 AND H16.
8. ☐ INSERT R3 ACROSS H20 AND H24.
9. ☐ CONNECT H12 TO J20 (WHT WIRE).
10. ☐ CONNECT L11 TO GROUND (WHT WIRE).
11. ☐ CONNECT L20 TO V3 (+4.5V) (WHT WIRE).
12. ☐ CONNECT SPRING 68 TO GROUND (BLU WIRE).
13. ☐ CONNECT SPRING 69 TO H25 (BLU WIRE).

2. TEST THE CIRCUIT

ROTATE THE KNOB ON THE 1M CONSOLE POT (R2) FULLY TO THE LEFT. PUSH THE POWER SWITCH ON AND YOU SHOULD HEAR A BUZZ COMING FROM THE SPEAKER. ROTATE R2'S KNOB TO THE RIGHT AND FREQUENCY OF THE BUZZ WILL RISE AND EVENTUALLY BECOME A TONE. IF THE TONE STOPS, ROTATE R2 BACK TO THE LEFT.

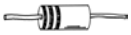
GOING FURTHER

YOU CAN CHANGE THE TONE TO A BUZZ BY INCREASING THE VALUE OF C1 FROM 0.01 UF TO 0.1 UF (104). YOU CAN SLOW THE BUZZ TO A SLOW SERIES OF POPS BY INCREASING C1 TO 10 UF. REMOVE 0.01 UF CAPACITOR AND INSTALL 10 UF CAPACITOR ACROSS J15 (+) AND H16 (-).

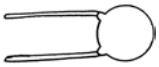
BUILD A COMPLEMENTARY VERSION OF THE SIMPLE TWO-TRANSISTOR OSCILLATOR

THE BASIC TWO-TRANSISTOR OSCILLATOR ON PAGE 56 PROVIDES A VERY NICE WAY TO DEMONSTRATE THE COMPLEMENTARY NATURE OF NPN AND PNP TRANSISTORS. THAT'S BECAUSE THE CIRCUIT WILL STILL WORK IF YOU EXCHANGE THE TWO TRANSISTORS AND REVERSE THEIR CONNECTIONS. IN EFFECT, THE NEW CIRCUIT IS A FLIPPED OVER VERSION OF THE ORIGINAL CIRCUIT. THE NEW CIRCUIT ACTUALLY WORKS BETTER THAN THE ORIGINAL CIRCUIT, SINCE AN NPN TRANSISTOR CONDUCTS CURRENT SLIGHTLY BETTER WHEN IT IS SWITCHED ON THAN DOES A PNP TRANSISTOR. THIS MEANS THE REVISED CIRCUIT CAN DELIVER MORE CURRENT TO THE SPEAKER OR WHATEVER ELSE IT IS DESIGNED TO DRIVE.

PARTS YOU WILL NEED



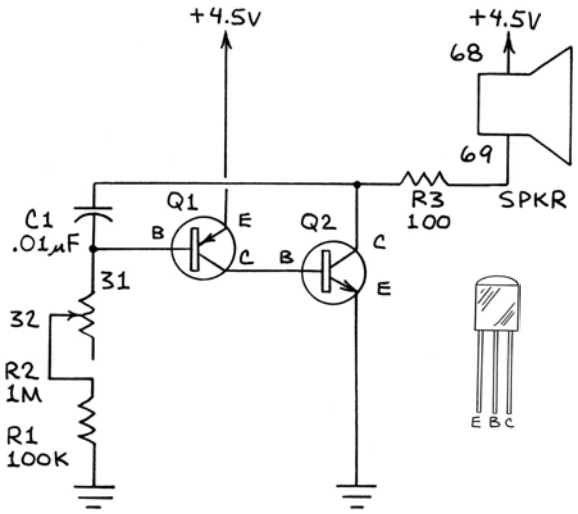
R1-100K (BRN-BLK-YEL)
R3-100 OHMS (BRN-BLK-BLK)



C1-0.01 UF CAPACITOR (103)

Q1-9015 PNP TRANSISTOR
Q2-9014 NPN TRANSISTOR

CIRCUIT DIAGRAM



HOW THE CIRCUIT WORKS.

YOU ALREADY KNOW HOW THE ORIGINAL VERSION OF THIS CIRCUIT WORKS. SO NOW IT'S YOUR TURN:

1. WHAT IS THE PURPOSE OF C1?
2. WHAT IS THE PURPOSE OF R1 AND R2?
3. WHAT IS THE PURPOSE OF R3?
4. WHICH TRANSISTOR SWITCHES ON FIRST, Q1 OR Q2?
4. TRUE OR FALSE: REDUCING THE RESISTANCE OF R2 INCREASES THE OSCILLATION FREQUENCY.
5. USE A COLORED PENCIL, PEN OR HIGHLIGHTER TO MARK THE CURRENT PATH WHEN CURRENT IS FLOWING THROUGH THE SPEAKER.

1. BUILD THE CIRCUIT

YOU CAN MODIFY THE CIRCUIT ON PAGE 56 BY SWITCHING THE POSITIONS OF Q1 AND Q2. THEN USE THE CIRCUIT DIAGRAM TO MOVE THE REMAINING PARTS. OR YOU CAN START FROM SCRATCH BY FOLLOWING THESE STEPS:

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT L13 (E), J13 (B) AND H13 (C).
3. ☐ INSERT Q2 AT L18 (E), J18 (B) AND H18 (C).
4. ☐ CONNECT R1 ACROSS SPRING 32 AND F1.
5. ☐ CONNECT F5 TO GROUND (RED WIRE).
6. ☐ CONNECT SPRING 31 TO J11 (RED WIRE).
7. ☐ INSERT C1 ACROSS J15 AND H16.
8. ☐ INSERT R3 ACROSS H20 AND H24.
9. ☐ CONNECT H12 TO J20 (WHT WIRE).
10. ☐ CONNECT L11 TO V3 (+4.5V) (WHT WIRE).
11. ☐ CONNECT L20 TO GROUND (WHT WIRE).
12. ☐ CONNECT SPRING 68 TO (+4.5V) (BLU WIRE).
13. ☐ CONNECT SPRING 69 TO H25 (BLU WIRE).

2. TEST THE CIRCUIT

ROTATE THE KNOB ON THE 1M CONSOLE POT (R2) FULLY TO THE LEFT. PUSH THE POWER SWITCH ON, AND YOU SHOULD HEAR A BUZZ COMING FROM THE SPEAKER. ROTATE R2'S KNOB TO THE RIGHT AND THE BUZZ WILL BECOME A TONE. THE TONE WILL HAVE A PURE, PLEASANT SOUND. IF THE TONE STOPS, ROTATE R2 BACK TO THE LEFT.

BUILD A SIMPLE TWO-TRANSISTOR RADIO TRANSMITTER

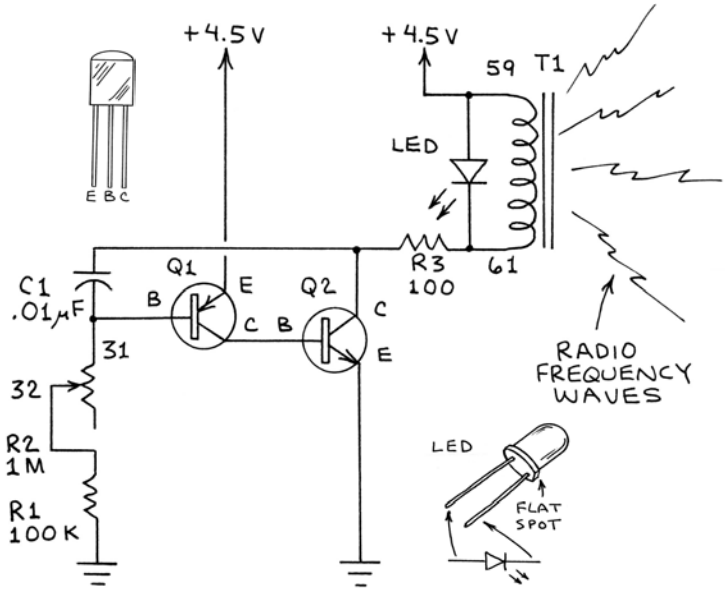
THE TRANSISTORS IN THE TWO-TRANSISTOR OSCILLATOR CIRCUITS ON PAGES 56 AND 57 SWITCH ON AND OFF VERY RAPIDLY (WITHIN A FEW TENS OF MICROSECONDS). SUCH FAST RISING AND FALLING PULSES GENERATE RADIO-FREQUENCY (RF) SIGNALS THAT CAN BE RECEIVED BY A NEARBY RADIO. THE TRANSFORMER AND RELAY INSTALLED ON YOUR LEARNING LAB CONSOLE HAVE WIRE COILS THAT CAN ENHANCE THE RADIO SIGNAL. YOU WILL CONNECT A TWO-TRANSISTOR OSCILLATOR TO THE TRANSFORMER TO FORM A SIMPLE, LOW-POWER RADIO FREQUENCY TRANSMITTER.

PARTS YOU WILL NEED

TWO-TRANSISTOR OSCILLATOR CIRCUIT ON PAGE 57 PLUS:

LED-GREEN LED

CIRCUIT DIAGRAM



2. TEST THE CIRCUIT

PLACE A SMALL BATTERY-POWERED AM BROADCAST BAND TRANSISTOR RADIO NEAR YOUR LEARNING LAB CONSOLE. CHECK YOUR WIRING FOR ERRORS AND PUSH THE POWER SWITCH ON. YOU SHOULD HEAR A BUZZ OR TONE FROM THE RADIO SPEAKER. MOVE THE RADIO AROUND THE CONSOLE UNTIL YOU FIND A PLACE WHERE THE SIGNAL IS LOUDEST. THEN ADJUST R2 TO CHANGE THE FREQUENCY OF THE SOUND. AS THE FREQUENCY INCREASES, THE LED WILL GLOW MORE BRIGHTLY. THE RADIO SIGNAL IS VERY BROAD AND CAN BE HEARD ACROSS THE ENTIRE BROADCAST BAND.

1. MODIFY THE CIRCUIT ON PAGE 57

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ MOVE BLUE WIRE AT SPRING 69 TO SPRING 61.
3. ☐ MOVE BLUE WIRE AT SPRING 68 TO SPRING 59.
4. ☐ INSERT LED ACROSS M26 (ANODE) AND P26 (CATHODE).
5. ☐ CONNECT SPRING 59 TO M30 (RED WIRE).
6. ☐ CONNECT SPRING 61 TO P30 (RED WIRE).

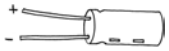
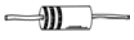
GOING FURTHER

PLACE A RADIO NEAR THE CIRCUIT ON PAGE 57. THE OSCILLATOR WILL SEND A SIGNAL TO THE RADIO EVEN WITHOUT BEING CONNECTED TO THE TRANSFORMER. THIS IS BECAUSE THE WIRING OF THE CIRCUIT ACTS LIKE AN ANTENNA THAT RADIATES THE SIGNAL. TUNE THE RADIO TO DETERMINE IF THERE ARE FREQUENCIES WHERE THE SIGNAL IS LOUDER OR QUIETER. NOTICE HOW THE OSCILLATOR SIGNAL AFECTS THE SIGNAL FROM RADIO STATIONS. TO INCREASE THE RANGE OF THE TRANSMITTER, MOVE THE POWER SUPPLY WIRES AT V3 (+4.5 VOLTS) TO V6 (+9 VOLTS). YOU WILL NEED TO REPLACE THE WHITE WIRE WITH A RED ONE.

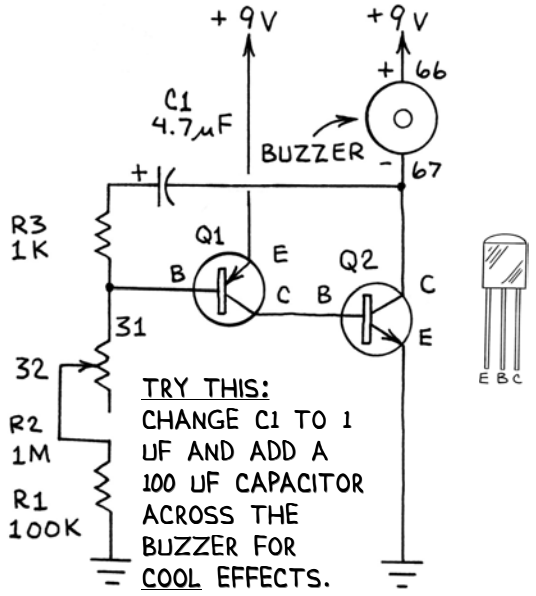
BUILD A TWO-TRANSISTOR CHIRPER

YOU WILL BUILD A TWO-TRANSISTOR OSCILLATOR THAT CAUSES THE BUZZER TO EMIT CHIRPS.

PARTS YOU WILL NEED

OSCILLATOR CIRCUIT ON PAGE 57 PLUS:  C1-4.7 UF  R3-1K (BRN-BLK-RED)

CIRCUIT DIAGRAM



1. MODIFY THE CIRCUIT ON PAGE 57

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE ORIGINAL R3 AND BLUE WIRE TO SPRING 69.
3. ☐ MOVE BLUE WIRE AT SPRING 68 TO SPRING 66.
4. ☐ CONNECT SPRING 67 TO H19 (BLU WIRE).
5. ☐ MOVE BLUE WIRE FROM V3 (+4.5V) TO V6 (+9V).
6. ☐ REMOVE WHITE WIRE BETWEEN L11 AND V3.
7. ☐ CONNECT L11 TO V6 (+9V) (RED WIRE).
8. ☐ INSERT R3 ACROSS J14 AND F14.
9. ☐ REMOVE ORIGINAL C1 (0.01 UF).
10. ☐ INSERT NEW C1 ACROSS F15 (+) AND H16 (-).

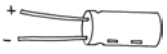
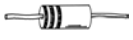
2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. PUSH THE POWER SWITCH ON. THE BUZZER WILL EMIT A SLOW SERIES OF CHIRPS. ADJUST R2 TO SPEED UP THE CHIRPS.

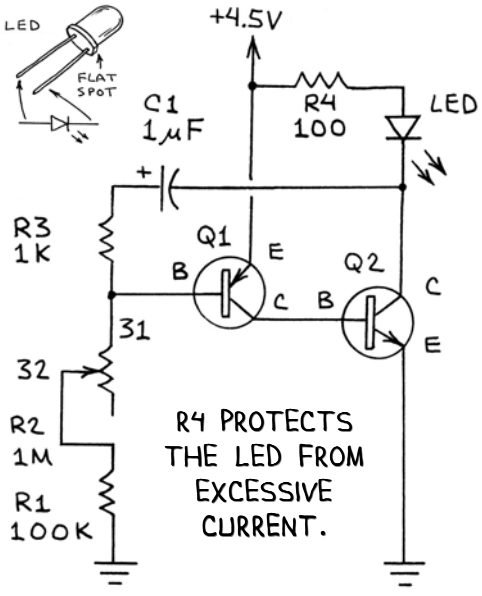
BUILD A TRANSISTOR LED FLASHER

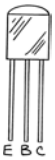
YOU WILL USE A TWO-TRANSISTOR OSCILLATOR TO FLASH AN LED.

PARTS YOU WILL NEED

CIRCUIT ABOVE PLUS:  C1-1 UF  R4-100 (BRN-BLK-BRN)  LED-GREEN

CIRCUIT DIAGRAM





1. BUILD THE CIRCUIT

MODIFY THE CIRCUIT ABOVE:

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE BLUE WIRES BETWEEN THE CIRCUIT AND SPRINGS 66 AND 67.
3. ☐ INSERT LED ACROSS E20 (ANODE) AND H20 (CATHODE).
4. ☐ REMOVE ORIGINAL C1 (4.7 UF).
5. ☐ INSERT NEW C1 ACROSS F15 (+) AND H16 (-).
6. ☐ INSERT R4 ACROSS E16 AND V3 (+4.5V).
7. ☐ MOVE RED WIRE AT V6 (+9V) TO V3 (+4.5V).

2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS AND THEN PUSH THE POWER SWITCH ON. ADJUST R2'S KNOB UNTIL THE LED FLASHES AT THE DESIRED RATE. BE SURE THAT THE LED FLASHES AND DOES NOT STAY ON TO KEEP Q2 FROM OVERHEATING.

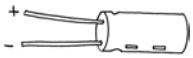
BUILD A TWO-TRANSISTOR DUAL-LED FLASHER

THERE ARE MANY WAYS TO FLASH LEDS ON AND OFF USING TRANSISTORS. THIS CIRCUIT IS ONE OF THE MOST STABLE AND RELIABLE OF LED FLASHERS. USING THE VALUES IN THE CIRCUIT DIAGRAM, THE LEDS ALTERNATELY FLASH ON AND OFF ABOUT ONCE PER SECOND. THE FLASH RATE IS EASILY CHANGED SIMPLY BY CHANGING ONE, OR BOTH, OF THE TIMING CAPACITORS (C1 AND C2). THIS CIRCUIT HAS PLENTY OF FUN AND PRACTICAL APPLICATIONS. IT ALSO DEMONSTRATES A VERY IMPORTANT KIND OF DIGITAL LOGIC CIRCUIT, THE ASTABLE OR FREE-RUNNING MULTIVIBRATOR. VERY SIMILAR CIRCUITS ARE USED TO SUPPLY A SERIES OF CLOCK PULSES TO DIGITAL LOGIC CIRCUITS. THE CIRCUIT FLIPS FIRST TO ONE STATE AND THEN FLOPS TO A SECOND STATE. SO YOU CAN THINK OF THE CIRCUIT YOU ARE ABOUT TO BUILD AS A FLIP-FLOP THAT CAN'T MAKE UP ITS MIND.

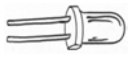
PARTS YOU WILL NEED

Q1, Q2-9015 PNP TRANSISTOR

R1, R4-470 OHM (YEL-VIO-BRN)
R2, R3-100K (BRN-BLK-YEL)

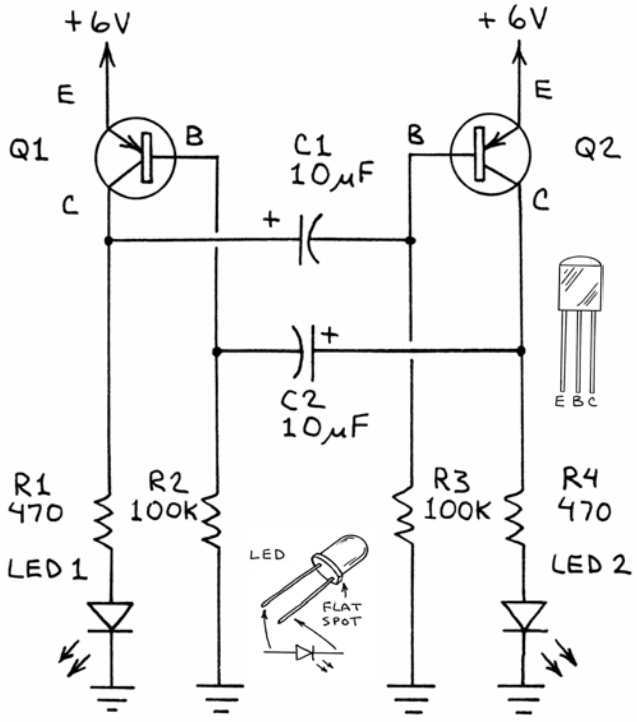


C1, C2-10 UF



LED 1-RED LED
LED 2-GREEN LED

CIRCUIT DIAGRAM



2. TEST THE CIRCUIT

IT'S EASY TO INSTALL THE TRANSISTORS BACKWARDS, SO BE SURE TO CHECK YOUR WIRING. ALSO, MAKE SURE YOU USED THE CORRECT TRANSISTORS. THEN PUSH THE POWER SWITCH ON. THE LEDS WILL BEGIN FLASHING ALTERNATELY AROUND ONE FLASH PER SECOND.

3. GOING FURTHER

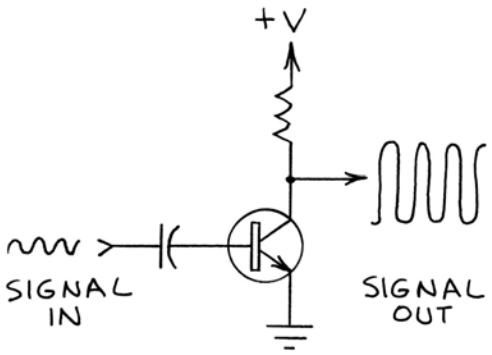
THE FLASH RATE IS CONTROLLED BY C1 AND C2. YOU CAN CHANGE THE FLASH RATE BY CHANGING THESE CAPACITORS. WHEN C1 AND C2 HAVE DIFFERENT VALUES, ONE LED WILL STAY ON LONGER THAN THE OTHER. THIS IS VERY ATTENTION-GETTING WHEN ONE LED FLASHES ON AND OFF BRIEFLY AND THE OTHER STAYS ON LONGER. TRY CHANGING C2 TO 0.47 UF TO SEE THIS EFFECT.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT H13 (E), J13 (B) AND L13 (C).
3. ☐ INSERT Q2 AT H18 (E), J18 (B) AND L18 (C).
4. ☐ INSERT R1 ACROSS L14 AND T14.
5. ☐ INSERT R4 ACROSS L17 AND T17.
6. ☐ INSERT R2 ACROSS J11 AND GROUND.
7. ☐ INSERT R3 ACROSS J20 AND GROUND.
8. ☐ INSERT C1 ACROSS L15 (+) AND J16 (-).
9. ☐ INSERT C2 ACROSS L16 (+) AND J15 (-).
10. ☐ INSERT LED 1 ACROSS T15 (ANODE) AND GROUND (CATHODE).
11. ☐ INSERT LED 2 ACROSS T16 (ANODE) AND GROUND (CATHODE).
12. ☐ CONNECT H11 AND V4 (+6V) (WHT WIRE).
13. ☐ CONNECT H20 AND V4 (+6V) (WHT WIRE).

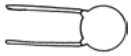
BUILD A ONE-TRANSISTOR AMPLIFIER WITH A SPEAKER OUTPUT

A TRANSISTOR AMPLIFIER CONVERTS A SMALL SIGNAL INTO A LARGER SIGNAL. IT DOES THIS BY ALLOWING THE SMALL SIGNAL TO CONTROL THE FLOW OF CURRENT THROUGH THE TRANSISTOR. IN THE BASIC CIRCUIT AT RIGHT, THE FLUCTUATING INPUT SIGNAL PASSES THROUGH A CAPACITOR AND ARRIVES AT THE BASE OF AN NPN TRANSISTOR. THERE IT MODULATES THE FLOW OF CURRENT FROM THE COLLECTOR TO THE EMITTER. THE OUTPUT APPEARS AT THE TRANSISTOR'S COLLECTOR. YOU WILL BUILD TWO VERSIONS OF THIS BASIC AMPLIFIER.



PARTS YOU WILL NEED

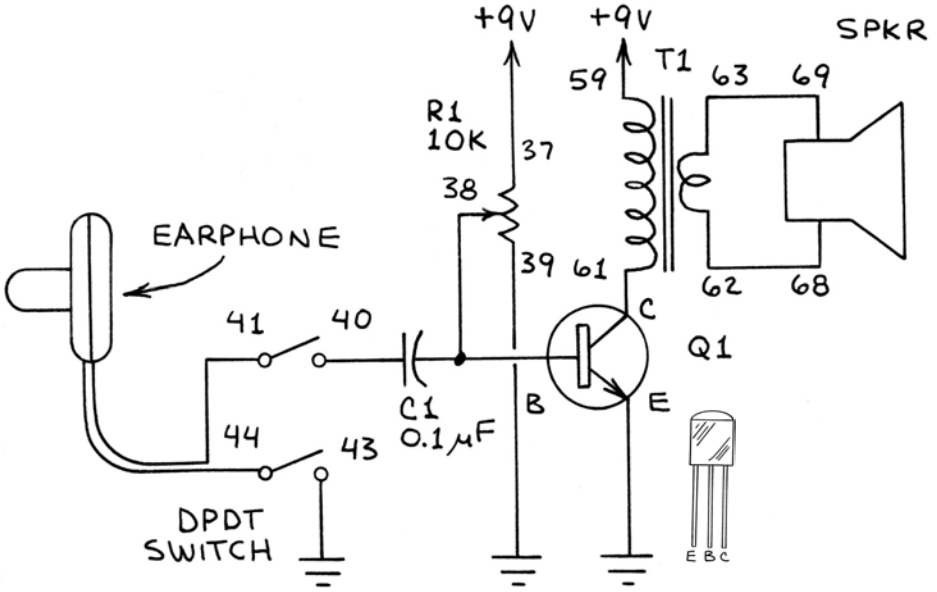
Q1-9014 NPN TRANSISTOR



C1-0.1 UF (104)

THE CERAMIC EARPHONE IS USED AS A MICROPHONE IN THIS CIRCUIT. THE DPDT SWITCH MUST BE CLOSED (PUSHED UP) TO CONNECT THE EARPHONE TO THE CIRCUIT.

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT L18 (E), J18 (B) AND H18 (C).
3. ☐ INSERT C1 ACROSS J15 AND J16.
4. ☐ CONNECT L20 TO GROUND (WHT WIRE).
5. ☐ CONNECT SPRING 59 TO V6 (+9V) (BLU WIRE).
6. ☐ CONNECT SPRING 61 TO H20 (BLU WIRE).
7. ☐ CONNECT SPRING 40 TO J11 (BLU WIRE).
8. ☐ CONNECT SPRING 43 TO GROUND (RED WIRE).
9. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
10. ☐ CONNECT SPRING 38 TO J17 (BLU WIRE).
11. ☐ CONNECT SPRING 37 TO V6 (+9V) (BLU WIRE).
12. ☐ CONNECT SPRINGS 62 AND 68 (RED WIRE).
13. ☐ CONNECT SPRINGS 63 AND 69 (RED WIRE).
14. ☐ CONNECT ONE PHONE LEAD TO SPRING 41.
15. ☐ CONNECT SECOND PHONE LEAD TO SPRING 44.

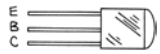
2. TEST THE CIRCUIT

CHECK FOR ERRORS. ROTATE THE 10K CONSOLE POT (R1) TO ITS MID-POINT. PUSH THE DPDT SWITCH UP TO CONNECT THE EARPHONE TO THE CIRCUIT. THEN PUSH THE POWER SWITCH UP. RUB THE EARPHONE, WHICH SERVES AS A MICROPHONE, AGAINST YOUR CLOTHING WHILE ROTATING R1'S KNOB. AT SOME POINT YOU WILL HEAR SCRATCHING SOUNDS FROM THE SPEAKER. ADJUST R1 UNTIL THE SOUNDS ARE LOUDEST. THE AMPLIFIER IS NOW WORKING. TEST IT BY PLACING THE EARPHONE/MICROPHONE NEXT TO THE SPEAKER OF A TRANSISTOR RADIO WHILE PLACING YOUR EAR NEAR THE CONSOLE SPEAKER. THE SOUND IS WEAK--WHICH IS WHY WE WILL ADD A SECOND TRANSISTOR LATER (PAGE 63). FIRST, LET'S REVERSE THE EARPHONE AND SPEAKER (SEE PAGE 62) AND FIND OUT WHAT HAPPENS.

BUILD A ONE-TRANSISTOR AMPLIFIER WITH AN EARPHONE OUTPUT

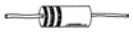
THE CIRCUIT ON PAGE 61 USES THE EARPHONE AS A MICROPHONE. YOU WILL NOW MODIFY THE AMPLIFIER SO THAT THE SPEAKER IS USED AS A MICROPHONE. THIS CIRCUIT IS NOT SUITABLE FOR PRACTICAL USE, SINCE THE OUTPUT IS VERY WEAK. IT'S IMPORTANCE IS THAT IT SHOWS HOW A SPEAKER, LIKE THE EARPHONE IN THE PREVIOUS CIRCUIT, CAN BE USED AS BOTH A SOURCE (SPEAKER) AND A DETECTOR (MICROPHONE) OF SOUND WAVES.

PARTS YOU WILL NEED



Q1-9014 NPN TRANSISTOR

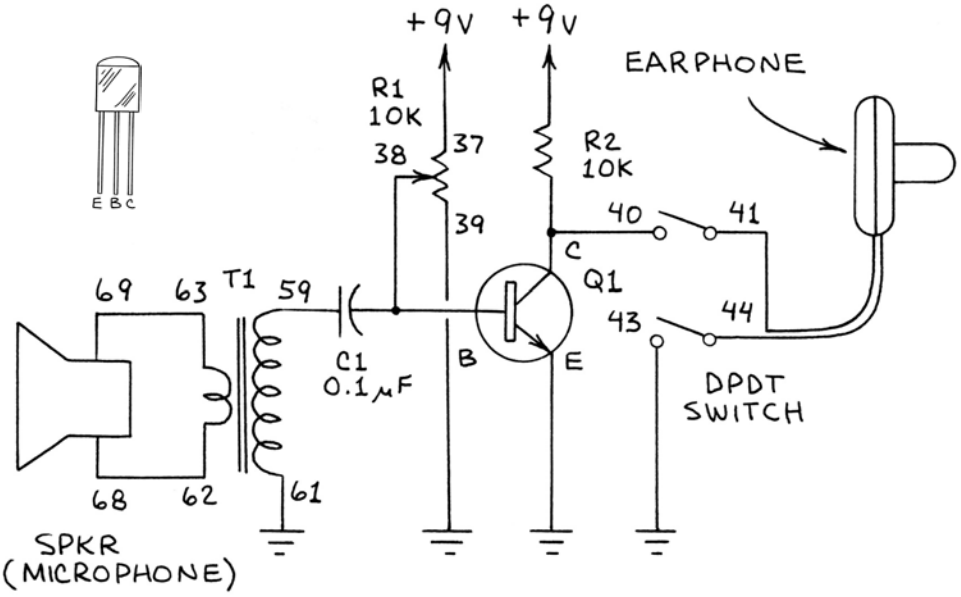
C1-0.1 UF (104)



R2-10K (BRN-BLK-ORG)

THE SPEAKER IS USED AS A MICROPHONE IN THIS CIRCUIT. CLOSE THE DPDT SWITCH TO CONNECT THE EARPHONE TO THE CIRCUIT'S OUTPUT.

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

THIS CIRCUIT IS A MODIFICATION OF THE CIRCUIT ON PAGE 61. IT'S BEST TO BUILD THIS VERSION FROM SCRATCH TO AVOID CONFUSION.

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT L18 (E), J18 (B) AND H18 (C).
3. ☐ INSERT C1 ACROSS J15 AND J16.
4. ☐ INSERT R2 ACROSS H20 AND V6 (+9V).
5. ☐ CONNECT SPRING 40 TO H16 (BLU WIRE).
6. ☐ CONNECT SPRING 43 TO GROUND (WHT WIRE).
7. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
8. ☐ CONNECT SPRING 38 TO J17 (BLU WIRE).
9. ☐ CONNECT SPRING 37 TO V6 (+9V) (BLU WIRE).
10. ☐ CONNECT SPRING 59 TO J11 (BLU WIRE).
11. ☐ CONNECT SPRING 61 TO GROUND (RED WIRE).
12. ☐ CONNECT SPRINGS 62 AND 68 (RED WIRE).
13. ☐ CONNECT SPRINGS 63 AND 69 (RED WIRE).
14. ☐ CONNECT ONE PHONE LEAD TO SPRING 41.
15. ☐ CONNECT SECOND PHONE LEAD TO SPRING 44.

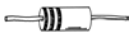
2. TEST THE CIRCUIT

DO <u>NOT</u> PLACE THE EARPHONE IN YOUR EAR UNTIL YOU CHECK FOR ERRORS. THEN ROTATE THE 10K CONSOLE POT (R1) TO ITS MID-POINT. PUSH THE DPDT SWITCH UP TO CONNECT THE EARPHONE TO THE CIRCUIT. THEN PUSH THE POWER SWITCH UP. NOW PLACE THE EARPHONE IN YOUR EAR--<u>BUT FOR THE FIRST TEST ALWAYS PLACE THE PHONE IN YOUR EAR BACKWARDS</u>. YOU WILL STILL BE ABLE TO HEAR ANY SOUNDS, AND YOUR EAR WILL BE PROTECTED SHOULD THE PHONE EMIT UNEXPECTEDLY LOUD POPS AND CRACKLES. NOW TAP ON THE CONSOLE SPEAKER WITH A PENCIL WHILE ADJUSTING THE 10K CONSOLE POT (R1). OR CONNECT THE BUZZER TO GROUND (SPRING 67) AND +6 VOLTS (SPRING 66). CUP YOUR HAND OVER THE SPEAKER AND BUZZER TO DIRECT SOUND TO THE SPEAKER WHILE ADJUSTING R1. AT SOME NARROW POINT YOU WILL HEAR THE PENCIL OR BUZZER THROUGH THE PHONE. ADJUST R1 UNTIL THE SOUND IS LOUDEST. THE AMPLIFIER IS NOW WORKING.

BUILD A TWO-TRANSISTOR AMPLIFIER

YOU WILL BUILD AN AMPLIFIER WITH ADDITIONAL COMPONENTS TO IMPROVE AUDIO RESPONSE AND A SECOND STAGE TO INCREASE GAIN. YOU WILL LEARN TO ADJUST THE AMPLIFIER.

PARTS YOU WILL NEED



R2-10K (BRN-BLK-ORG)
R4, R5-100 OHMS (BRN-BLK-BRN)

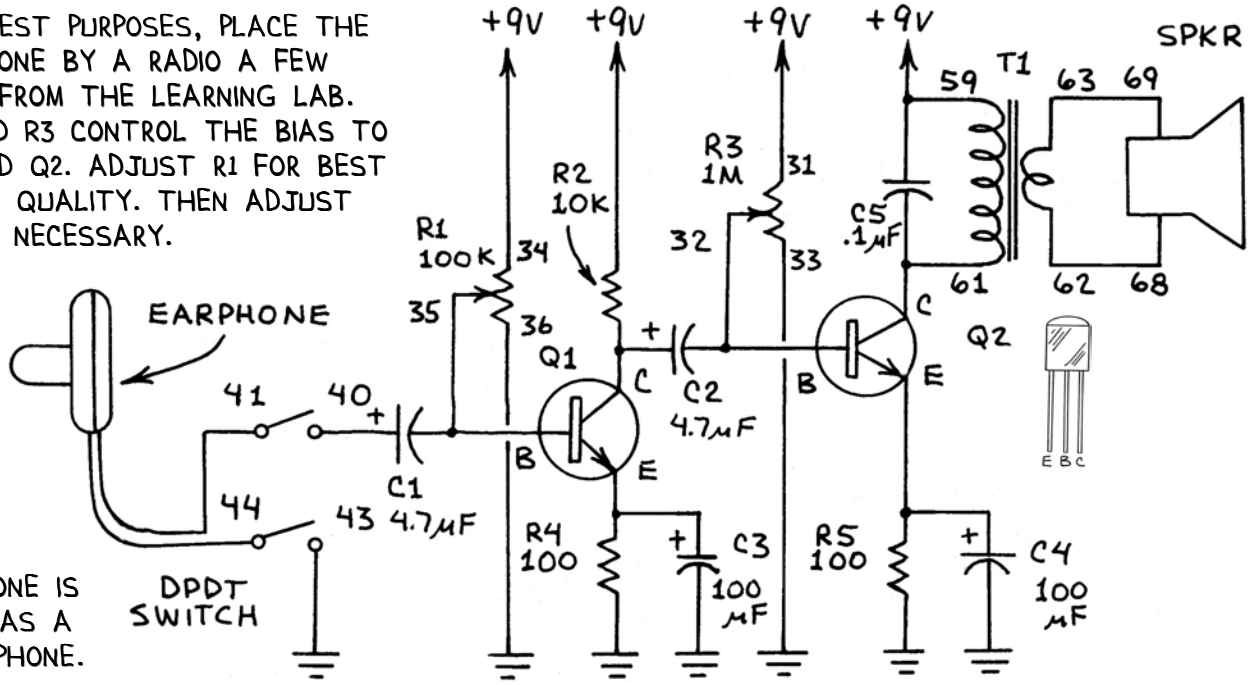
C1, C2-4.7 UF
C3, C4-100 UF

C5-0.1 UF (104)

Q1, Q2-9014 NPN

CIRCUIT DIAGRAM

FOR TEST PURPOSES, PLACE THE EARPHONE BY A RADIO A FEW FEET FROM THE LEARNING LAB. R1 AND R3 CONTROL THE BIAS TO Q1 AND Q2. ADJUST R1 FOR BEST SOUND QUALITY. THEN ADJUST R3 AS NECESSARY.



EARPHONE IS USED AS A MICROPHONE.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT L18 (E), J18 (B) AND H18 (C).
3. ☐ INSERT C1 ACROSS J15 AND J16.
4. ☐ INSERT R2 ACROSS H20 AND V6 (+9V).
5. ☐ INSERT R4 ACROSS L16 AND GROUND.
6. ☐ INSERT C3 ACROSS L20 (+) AND GROUND (-).
7. ☐ CONNECT ONE PHONE LEAD TO SPRING 41.
8. ☐ CONNECT SECOND PHONE LEAD TO SPRING 44.
9. ☐ CONNECT SPRING 43 TO GROUND (WHT WIRE).
10. ☐ CONNECT SPRING 40 TO J11 (BLU WIRE).
11. ☐ CONNECT SPRING 36 TO GROUND (RED WIRE).
12. ☐ CONNECT SPRING 35 TO J17 (BLU WIRE).
13. ☐ CONNECT SPRING 34 TO V6 (+9V) (BLU WIRE).
14. ☐ INSERT Q2 AT L23 (E), J23 (B) AND H23 (C).
15. ☐ INSERT C2 ACROSS H19 (+) AND J21 (-).
16. ☐ INSERT R5 ACROSS L21 AND GROUND.
17. ☐ INSERT C4 ACROSS L25 (+) AND GROUND (-).
18. ☐ CONNECT SPRING 33 TO GROUND (RED WIRE).
19. ☐ CONNECT SPRING 32 TO J22 (BLU WIRE).
20. ☐ CONNECT SPRING 31 TO V6 (+9V) (BLU WIRE).
21. ☐ CONNECT C5 ACROSS SPRINGS 59 AND 61.
22. ☐ CONNECT SPRING 61 TO H25 (BLU WIRE).
23. ☐ CONNECT SPRING 59 TO V6 (+9V) (BLU WIRE).
24. ☐ CONNECT SPRINGS 62 AND 68 (RED WIRE).
25. ☐ CONNECT SPRINGS 63 AND 69 (RED WIRE).

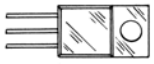
2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. THEN PUSH THE POWER SWITCH ON AND THE DPDT SWITCH UP. ADJUST THE 100K AND 1M CONSOLE POTS AS DESCRIBED ABOVE FOR BEST SOUND QUALITY. IF A RADIO ISN'T AVAILABLE, TAP OR RUB ON THE MICROPHONE TO CREATE SOME SOUND.

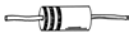
BUILD A POWER FET VARIABLE RESISTOR

YOU WILL USE A POWER FET TO CONTROL THE BRIGHTNESS OF AN LED.

PARTS YOU WILL NEED



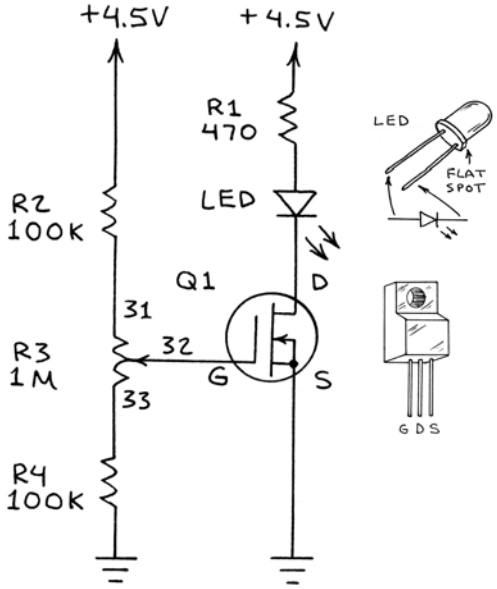
Q1-POWER FET



R1-470 OHMS (YEL-VIO-BRN)
R2, R4-100K (BRN-BLK-YEL)

LED-GREEN

CIRCUIT DIAGRAM



R3 IS A VOLTAGE DIVIDER THAT TURNS Q1 ON GRADUALLY.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT R16 (G), Q16 (D) AND P16 (S).
3. ☐ INSERT LED ACROSS F18 (ANODE) AND G18 (CATHODE).
4. ☐ INSERT R1 ACROSS F16 AND V3 (+4.5V).
5. ☐ INSERT R2 ACROSS E12 AND V3 (+4.5V).
6. ☐ INSERT R4 ACROSS P12 AND GROUND.
7. ☐ CONNECT SPRING 31 AND E11 (RED WIRE).
8. ☐ CONNECT SPRING 32 AND R18 (BLU WIRE).
9. ☐ CONNECT SPRING 33 AND P11 (RED WIRE).
10. ☐ CONNECT P20 TO GROUND (WHT WIRE).
11. ☐ CONNECT G20 TO Q20 (WHT WIRE).

2. TEST THE CIRCUIT

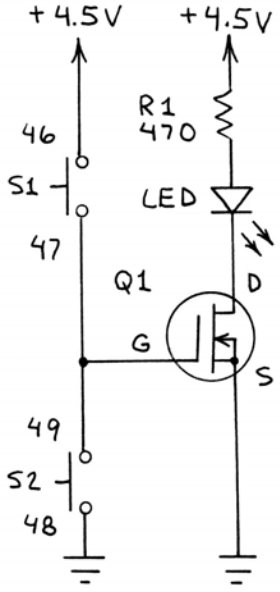
CHECK YOUR WIRING FOR ERRORS. PUSH THE POWER SWITCH ON. ROTATE THE 1M CONSOLE POT'S (R3) KNOB TO CHANGE THE BRIGHTNESS OF THE LED FROM OFF TO FULLY ON.

BUILD A POWER FET TOUCH SWITCH

YOU WILL USE A POWER FET TO MAKE A VERSATILE TOUCH-ON/TOUCH-OFF SWITCH.

CIRCUIT DIAGRAM

<u>CAUTION:</u> DO <u>NOT</u> PRESS S1 AND S2 AT THE SAME TIME. THIS WILL APPLY A DIRECT SHORT CIRCUIT ACROSS THE POWER SUPPLY.



1. MODIFY THE CIRCUIT ABOVE

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE R2 AND R4.
3. ☐ REMOVE RED WIRES AT SPRINGS 31 AND 33.
4. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
5. ☐ CONNECT SPRING 48 TO GROUND (RED WIRE).
6. ☐ CONNECT SPRING 46 TO V3 (+4.5V) (BLU WIRE).
7. ☐ MOVE BLUE WIRE AT SPRING 32 TO SPRING 47.

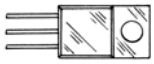
2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS AND THEN PUSH THE POWER SWITCH ON. PRESS AND RELEASE S1, AND THE LED WILL GLOW. PRESS AND RELEASE S2, AND THE LED WILL SWITCH OFF. (<u>CAUTION: DO NOT PRESS S1 AND S2 AT THE SAME TIME.</u>) NOW SIMPLY TOUCH YOUR INDEX FINGER ACROSS SPRINGS 46 AND 47. THE LED SHOULD GLOW. TURN THE LED OFF BY TOUCHING SPRINGS 48 AND 49. OK TO REPLACE THE LED AND R1 WITH THE BUZZER OR RELAY. WORKS GREAT.

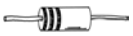
BUILD A POWER FET TIMER THAT LIGHTS AN LED DURING THE TIMING CYCLE

YOU WILL BUILD A SIMPLE BUT USEFUL FET TIMER CIRCUIT. MAKES A GOOD TELEPHONE TIMER.

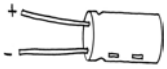
PARTS YOU WILL NEED



Q1-POWER FET



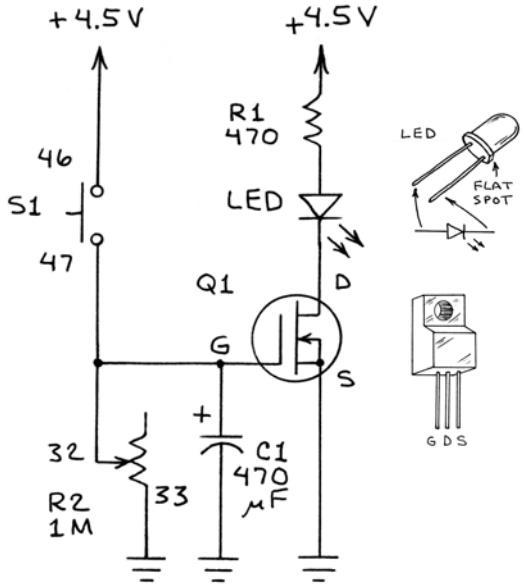
R1-470 OHMS (YEL-VIO-BRN)



C1-470 UF

LED-GREEN

CIRCUIT DIAGRAM



CHANGE R2 TO 100K CONSOLE POT FOR FASTER TIMING CYCLES.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT Q1 AT R16 (G), Q16 (D) AND P16 (S).
3. ☐ INSERT R1 ACROSS F16 AND V3 (+4.5V).
4. ☐ INSERT LED ACROSS F18 (ANODE) AND G18 (CATHODE).
5. ☐ INSERT C1 ACROSS R20 (+) AND GROUND (-).
6. ☐ CONNECT G20 AND Q20 (WHT WIRE).
7. ☐ CONNECT P20 AND GROUND (WHT WIRE).
8. ☐ CONNECT SPRING 33 TO GROUND (RED WIRE).
9. ☐ CONNECT SPRING 32 TO R18 (BLU WIRE).
10. ☐ CONNECT SPRING 46 TO V3 (+4.5V) (BLU WIRE).
11. ☐ CONNECT SPRING 47 TO R17 (RED WIRE).

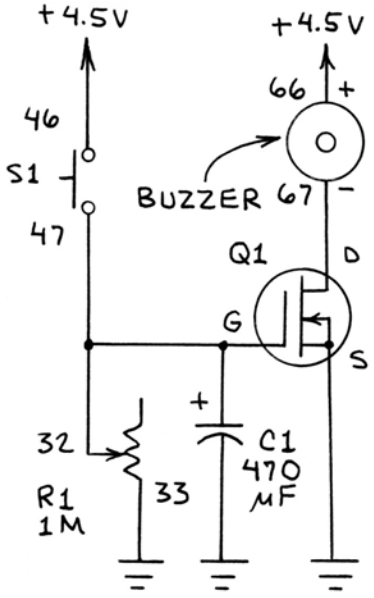
2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. PUSH THE POWER SWITCH ON. PRESS AND RELEASE S1. THE LED WILL GLOW UP TO SEVERAL MINUTES. ADJUST THE 1M CONSOLE POT (R2) TO REDUCE THE GLOW TIME.

BUILD A POWER FET TIMER THAT BUZZES DURING THE TIMING CYCLE

YOU WILL MODIFY THE TIMER ABOVE TO DRIVE A BUZZER INSTEAD OF AN LED.

CIRCUIT DIAGRAM



1. MODIFY THE CIRCUIT ABOVE

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE R1 AND THE LED.
3. ☐ REMOVE WHITE WIRE ACROSS G20 AND Q20.
4. ☐ CONNECT SPRING 67 TO Q18 (BLU WIRE).
5. ☐ CONNECT SPRING 66 TO V3 (+4.5V) (BLU WIRE).

2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS AND THEN PUSH THE POWER SWITCH ON. PRESS AND RELEASE S1 AND THE BUZZER WILL SOUND UNTIL C1 DISCHARGES THROUGH R1, WHICH CONTROLS THE LENGTH OF THE TIMING CYCLE. THIS CIRCUIT CAN BE ADAPTED TO PROVIDE A WARNING TONE WHEN A LIGHT OR APPLIANCE IS LEFT SWITCHED ON. USE A SMALLER VALUE FOR C1 FOR BRIEF TIMING CYCLES.

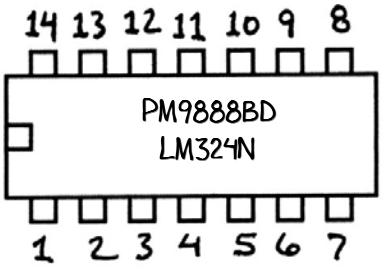
ANALOG ICS PROVIDED WITH YOUR ELECTRONICS LEARNING LAB

YOUR LEARNING LAB IS SUPPLIED WITH THESE ANALOG LOGIC CHIPS:

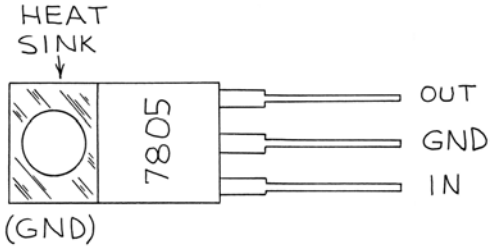
7805 VOLTAGE REGULATOR	272 DUAL OP AMP	386 POWER AMPLIFIER
324 QUAD OP AMP	339 QUAD COMPARATOR	555 TIMER
4046 PHASE LOCKED LOOP		

ANALOG ICS MARKINGS AND IDENTIFICATION

THE ANALOG CHIPS SUPPLIED WITH YOUR LEARNING LAB ARE INSTALLED IN DUAL-IN-LINE PACKAGES OR "DIPS" WITH AN INDEX MARKER (A NOTCH) NEAR PIN 1. ROWS OF NUMBERS AND A LOGO OR SYMBOL ARE PRINTED ON EACH DIP. THE PART NUMBER MAY BE ON ANY ROW, AND IT WILL HAVE A PREFIX (LM, TLS, ETC.) AND OTHER CHARACTERS. LOOK AT THE CHIP AT RIGHT. DO YOU SEE ONE OF THE PART NUMBERS ABOVE? (IT'S A 324 QUAD OP AMP.) THE OTHER NUMBERS ARE MANUFACTURING AND DATE CODES. IF THE NUMBER IS FAINT, SHINE BRIGHT LIGHT ON THE IC. YOU MAY NEED TO TILT THE IC TO SEE THE NUMBER.



7805 VOLTAGE REGULATOR



THE 7805 VOLTAGE REGULATOR IC IS DESIGNED TO PROVIDE A CONSTANT 5-VOLTS WHEN POWERED BY FROM ABOUT 7.3 TO 35 VOLTS. THE 7805 WAS ORIGINALLY DESIGNED TO POWER THE TTL FAMILY OF DIGITAL INTEGRATED CIRCUITS. IT IS IDEAL FOR POWERING ANY CIRCUIT THAT REQUIRES A VERY STABLE 5 VOLT POWER SUPPLY.

7805 SPECIFICATIONS

TYPICAL OUTPUT VOLTAGE: A TYPICAL 7805 DELIVERS 5 VOLTS. SOME MAY PROVIDE AS LITTLE AS 4.8 OR AS MUCH AS 5.2 VOLTS.

LOAD REGULATION: THE LOAD IS TYPICALLY REGULATED TO WITHIN 10 MILLIVOLTS AND NO MORE THAN 50 MILLIVOLTS.

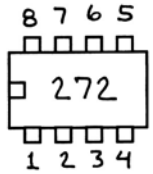
PEAK OUTPUT CURRENT: THE TO220 VERSION OF 7805 PROVIDED WITH YOUR LEARNING LAB WILL DELIVER MORE THAN ONE AMPERE OF CURRENT TO A LOAD IF THE CHIP'S ALUMINUM HEATSINK TAB IS BOLTED TO AN APPROPRIATE HEATSINK.

INTERNAL OVERLOAD PROTECTION: SHOULD THE 7805 BE OPERATED BEYOND ITS SPECIFICATIONS AND BEGIN TO OVERHEAT, A SPECIAL THERMAL OVERLOAD CIRCUIT WILL AUTOMATICALLY DISABLE THE CHIP UNTIL THE TEMPERATURE RETURNS TO A SAFE LEVEL.

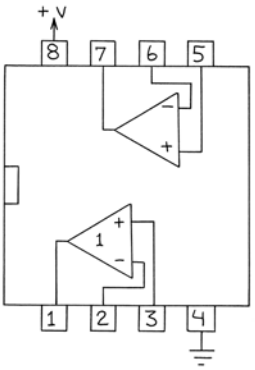
MINIMUM REQUIRED INPUT VOLTAGE TO PROVIDE 5 VOLTS OUTPUT: 7.3 VOLTS. BELOW 7.3 VOLTS THE CHIP MAY NOT PROVIDE A STABLE 5 VOLTS.

OTHER 7805 VERSIONS: THE 7805 IS AVAILABLE IN VARIOUS VERSIONS. THE TO-3 VERSION COMES IN AN ALL-METAL CAN FOR OPTIMUM HEAT SINKING. A SMALL PLASTIC VERSION PROVIDES UP TO 100 MILLIAMPERES FOR LOW POWER CIRCUITS.

272 DUAL-OP AMP



THE 272 (OR TLS272) IS A PACKAGE OF TWO PRECISION OPERATIONAL AMPLIFIERS THAT CAN BE POWERED BY A BATTERY OR OTHER SINGLE-POLARITY SUPPLY. THE TWO OP AMPS ARE INSTALLED IN A SINGLE 8-PIN PACKAGE. THE OUTPUTS OF ALL OP AMPS HAVE A SMALL ERROR VOLTAGE CALLED THE OFFSET. THE 272 OFFSET VOLTAGE IS 1 MILLIVOLT OR LESS WHEN THE GAIN IS 1. BOTH OP AMPS HAVE A VERY HIGH INPUT IMPEDANCE.



272 SPECIFICATIONS

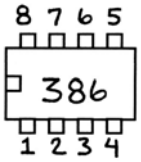
SUPPLY VOLTAGE RANGE: +3 VOLTS TO +16 VOLTS.

SUPPLY CURRENT: 1.4 MILLIAMPERES TYPICAL (3.2 MA MAXIMUM).

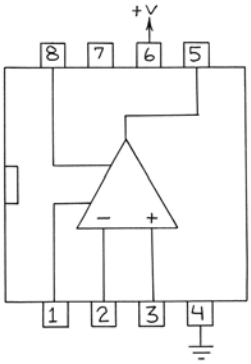
OUTPUT CURRENT: + OR - 30 MILLIAMPERES TYPICAL (10 MA MINIMUM)

MAXIMUM VOLTAGE GAIN: 23,000 TYPICAL (5,000 MINIMUM) AT ROOM TEMPERATURE AND WHEN POWERED BY +5 VOLTS. GAIN IS SET BY A FEEDBACK RESISTOR BETWEEN THE OUTPUT AND THE INVERTING (-) INPUT.

386 AUDIO POWER AMPLIFIER



THE 386 (OR LM386) IS A LOW VOLTAGE AMPLIFIER DESIGNED SPECIFICALLY FOR AUDIO APPLICATIONS. THE GAIN IS INTERNALLY SET TO 20. THE GAIN CAN BE INCREASED TO 200 BY CONNECTING A 10-UF CAPACITOR ACROSS PINS 1 (+) AND 8 (-). A RESISTOR IN SERIES WITH THE CAPACITOR CAN REDUCE THE GAIN TO BETWEEN 20 AND 200. THE 386 IS DESIGNED FOR BATTERY OPERATION. IT HAS LOW DISTORTION. APPLICATIONS INCLUDE DRIVING SPEAKERS IN RADIOS, INTERCOMS AND TAPE PLAYERS.



386 SPECIFICATIONS

SUPPLY VOLTAGE RANGE: +4 VOLTS TO +12 VOLTS.

SUPPLY CURRENT (NO INPUT SIGNAL): 4 MILLIAMPERES TYPICAL (8 MA MAXIMUM).

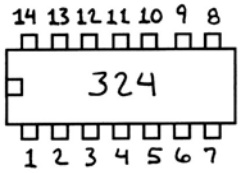
OUTPUT POWER: 325 MILLIWATTS TYPICAL (250 MA MINIMUM) WHEN POWERED BY 6 VOLTS.

VOLTAGE GAIN: 26 DB (20) TYPICAL. 46 DB (200) WITH 10-UF CAPACITOR BETWEEN PINS 1 AND 8.

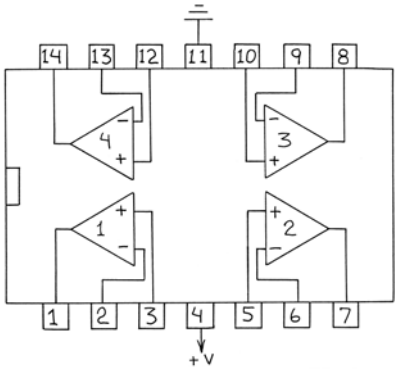
FREQUENCY BANDWIDTH: 300 KHZ (300,000 HZ) TYPICAL.

TOTAL HARMONIC DISTORTION: 0.2% TYPICAL.

324 QUAD OP AMP



THE 324 (OR LM324) IS A PACKAGE OF FOUR OPERATIONAL AMPLIFIERS THAT CAN BE POWERED BY A BATTERY OR OTHER SINGLE-POLARITY SUPPLY OVER A VERY WIDE VOLTAGE RANGE. THE FOUR OP AMPS ARE INSTALLED IN A SINGLE 14-PIN PACKAGE. YOU CAN USE ONLY ONE OF THE OP AMPS OR ALL FOUR. CURRENT CONSUMPTION IS UNAFFECTED BY THE POWER SUPPLY VOLTAGE. THE 324 HAS NUMEROUS APPLICATIONS.



324 SPECIFICATIONS

SUPPLY VOLTAGE RANGE: +3 VOLTS TO +30 VOLTS.

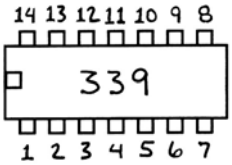
SUPPLY CURRENT: 0.8 MILLIAMPERES.

OUTPUT CURRENT (OUTPUT TO GROUND): 20 MILLIAMPERS TYPICAL (10 MA MINIMUM).

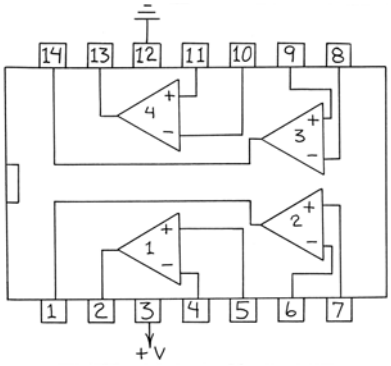
OUTPUT CURRENT (POSITIVE SUPPLY TO OUTPUT): 8 MILLIAMPERES TYPICAL (5 MA MINIMUM).

MAXIMUM VOLTAGE GAIN (TYPICAL): 100,000. GAIN IS SET BY A FEEDBACK RESISTOR BETWEEN OUTPUT AND INVERTING (-) INPUT.

339 QUAD COMPARATOR



THE 339 (OR LM339) IS A PACKAGE OF FOUR COMPARATORS. A COMPARATOR IS AN OP AMP DESIGNED TO OPERATE AT ITS MAXIMUM GAIN SO THAT THE OUTPUT IS EITHER FULLY ON OR FULLY OFF. THE 339 CAN BE POWERED BY A BATTERY OR OTHER SINGLE-POLARITY SUPPLY OVER A VERY WIDE VOLTAGE RANGE. ALL FOUR COMPARATORS ARE INSTALLED IN A SINGLE 14-PIN PACKAGE. THE 339 HAS MANY APPLICATIONS.



339 SPECIFICATIONS

SUPPLY VOLTAGE RANGE: +2 VOLTS TO +36 VOLTS.

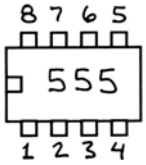
SUPPLY CURRENT: 0.8 MILLIAMPERES.

OUTPUT CURRENT (POSITIVE SUPPLY TO OUTPUT): 16 MILLIAMPERES TYPICAL (6 MA MINIMUM).

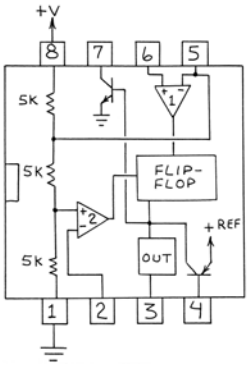
MAXIMUM VOLTAGE GAIN (TYPICAL): 200,000 (50,000 MINIMUM). NO FEEDBACK RESISTOR NECESSARY.

RESPONSE TIME FOR SWITCHING PURPOSES (TYPICAL): 1.3 MICROSECONDS.

555 TIMER (COMBINED ANALOG AND DIGITAL CHIP)



THE 555 (OR NE555) IS ONE OF THE MOST POPULAR INTEGRATED CIRCUITS EVER. THE 555 CAN BE USED AS AN OSCILLATOR OR TO PROVIDE PRECISE TIMING DELAYS. BOTH OPERATING MODES CAN BE CONTROLLD BY A SINGLE CAPACITOR OR RESISTOR. THE OUTPUT OF THE 555 CAN DRIVE A SPEAKER OR A SMALL RELAY. THE OUTPUT CAN ACT AS A SOURCE (OUTPUT DEVICE FROM PIN 3 TO GROUND) OR A SINK (OUTPUT DEVICE FROM POSITIVE SUPPLY TO PIN 3). NOTE THAT THE 555 INCLUDES A FLIP-FLOP. THIS MAKES IT A COMBINED ANALOG AND DIGITAL IC.



555 SPECIFICATIONS

SUPPLY VOLTAGE RANGE: +4.5 VOLTS TO +16 VOLTS.

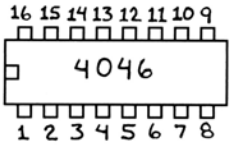
SUPPLY CURRENT: 3 MILLIAMPERES TYPICAL (5 MA MAXIMUM) WHEN SUPPLY IS +5 VOLTS.

OUTPUT CURRENT: + OR - 200 MILLIAMPERES MAXIMUM.

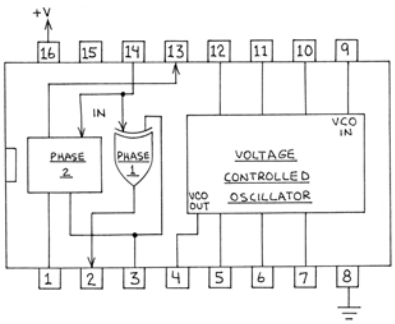
OUTPUT VOLTAGE RANGE (5 VOLT SUPPLY): 0.1 TO 3.3 VOLTS FOR 10 MA OUTPUT CURRENT.

SENSITIVITY OF TIMING INTERVAL TO SUPPLY VOLTAGE: 0.1% TYPICAL (0.5% MAXIMUM) WHEN USED IN A MONOSTABLE MODE (OUTPUT CHANGES STATE AFTER A FIXED TIME INTERVAL).

4046 PHASE-LOCKED LOOP (COMBINED ANALOG AND DIGITAL CHIP)



A PHASE-LOCKED LOOP (PLL) HAS A VOLTAGE-CONTROLLED OSCILLATOR (VCO). THE VCO SIGNAL AND AN INPUT SIGNAL ARE SENT VTO A PHASE COMPARATOR THAT GENERATES AN ERROR VOLTAGE PROPORTIONAL TO ANY DIFFERENCE IN FREQUENCY BETWEEN THE TWO SIGNALS. THE ERROR VOLTAGE ADJUSTS THE VCO FREQUENCY TO MATCH THAT OF THE INPUT SIGNAL. THUS THE PLL CAN TRACK AN INCOMING SIGNAL. OR ONLY THE VCO FUNCTION CAN BE USED.



4046 SPECIFICATIONS AND CMOS USE AND HANDLING PRECAUTIONS

SUPPLY VOLTAGE RANGE: +3 VOLTS TO +18 VOLTS VCO FREQUENCY LINEARITY: 1% TYPICAL.

THE 4046 IS A CMOS CHIP THAT REQUIRES SPECIAL TREATMENT. THERE'S MUCH MORE ABOUT CMOS CHIPS IN YOUR DIGITAL LOGIC WORKBOOK. FOR NOW, FOLLOW THESE GUIIDELINES:

1. CONNECT UNUSED INPUTS (PINS 3, 5, 9 AND 14) TO GROUND OR THE POSITIVE SUPPLY VOLTAGE. PINS 6, 7, 10, 11, 12 AND 15 SHOULD BE LEFT DISCONNECTED IF UNUSED.

2. THE VOLTAGE AT A CMOS GATE INPUT MUCH NOT EXCEED THE SUPPLY VOLTAGE.

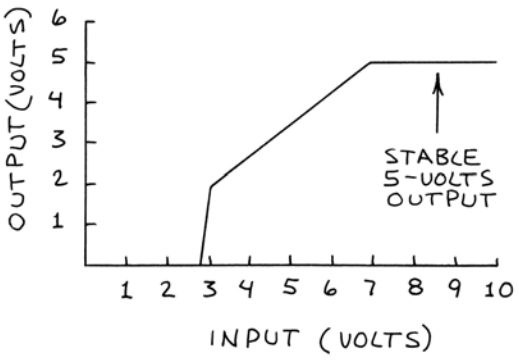
3. NEVER INSERT OR REMOVE A CMOS CHIP INTO OR FROM THE BREADBOARD OF YOUR LEARNING LAB UNLESS THE POWER SWITCH IS OFF.

VOLTAGE REGULATORS AND HOW TO USE THEM

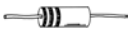
OFTEN A CIRCUIT REQUIRES A VERY STABLE VOLTAGE SOURCE OR A LOWER VOLTAGE THAN THAT PROVIDED BY BATTERIES OR A TRANSFORMER-TYPE POWER SUPPLY. VOLTAGE REGULATOR ICS FULFILL THIS REQUIREMENT BY PROVIDING A FIXED OR ADJUSTABLE VOLTAGE FROM AN EXTERNAL POWER SOURCE.

BUILD A BASIC 7805 5-VOLT REGULATOR

THE 7805 IS A WELL ESTABLISHED MEMBER OF A FAMILY OF STANDARD REGULATORS THAT PROVIDE VARIOUS OUTPUT VOLTAGES FOR A RANGE OF INPUT VOLTAGES. THE 7805 PROVIDES A VERY STABLE 5-VOLT OUTPUT WHEN POWERED BY AN INPUT VOLTAGE OF FROM ABOUT 7.5 TO 35 VOLTS. THE GRAPH SHOWS HOW THE OUTPUT VOLTAGE FLATTENS OUT AT 5-VOLTS, EVEN WHEN THE INPUT VOLTAGE EXCEEDS 7.5 VOLTS. YOU WILL BUILD A BASIC 7805 5-VOLT REGULATOR. YOU WILL LEARN HOW TO ADD CAPACITORS FOR CERTAIN USES.



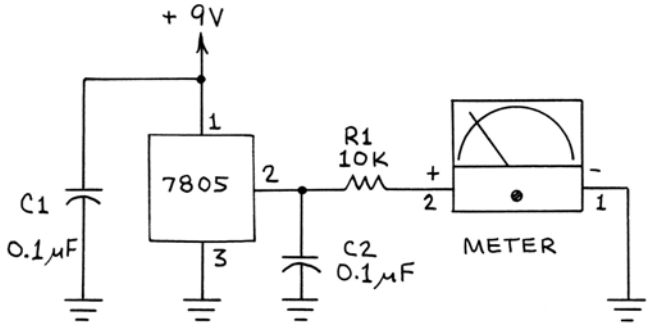
PARTS YOU WILL NEED



R1-10K (BRN-BLK-ORG) C1, C2-0.1 UF (104)

NOTICE THE UNUSUAL 7805 PIN NUMBER ARRANGEMENT. ALWAYS REMEMBER THAT THE CENTER PIN IS GROUND.

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT THE 7805 AT J8 (PIN 1), K8 (PIN 3) AND L8 (PIN 2).
3. ☐ INSERT C1 ACROSS J10 AND K10.
4. ☐ INSERT C2 ACROSS K7 AND L7.
5. ☐ INSERT R1 ACROSS L10 AND P10.
6. ☐ CONNECT J6 TO V6 (+9V) (BLU WIRE).
7. ☐ CONNECT K6 TO GROUND (WHT WIRE).
8. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
9. ☐ CONNECT SPRING 2 TO P8 (YEL WIRE).

2. TEST THE CIRCUIT

WHILE THE CIRCUIT IS VERY SIMPLE, THE UNUSUAL PIN NUMBERING ARRANGEMENT OF THE 7805 MEANS IT IS EASY TO MAKE A MISTAKE. SO CHECK YOUR WIRING VERY CAREFULLY. BE SURE THAT BARE LEADS DO NOT TOUCH ONE ANOTHER. THE METAL HEAT SINK OF THE 7805 IS INTERNALLY CONNECTED TO GROUND (PIN 3, THE CENTER PIN). SO BE SURE NO WIRES TOUCH THE METAL HEAT SINK. PROTECT THE METER BY MAKING SURE THAT R1 IS A 10K RESISTOR AND NOT A 1K RESISTOR. PUSH THE POWER SWITCH ON, AND THE METER WILL INDICATE ABOUT 0.5 MILLIAMPERE, OR 5 VOLTS. USE A RADIOSHACK MULTIMETER FOR A MORE ACCURATE READING.

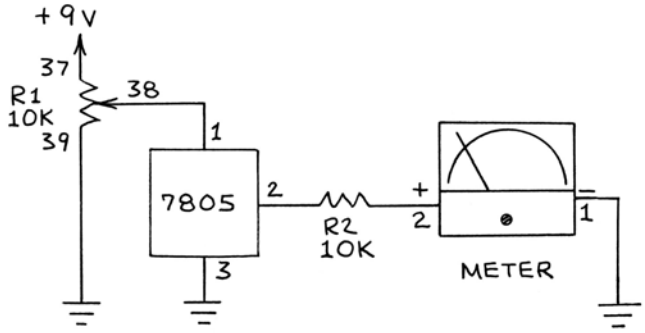
3. GOING FURTHER

C1 AND C2 ARE OPTIONAL WHEN THE 7805 IS CLOSE TO THE BATTERIES AND THE CIRCUIT TO BE POWERED. THAT'S THE CASE WITH YOUR LEARNING LAB CONSOLE, SO REMOVE C1 AND C2. DOES THE METER READING CHANGE?

BUILD A 7805 DEMONSTRATION REGULATOR

YOU WILL TEST THE 7805 REGULATOR BY VARYING THE INPUT VOLTAGE AT PIN 1 WHILE WATCHING THE OUTPUT VOLTAGE AT PIN 2.

CIRCUIT DIAGRAM



1. MODIFY THE BASIC 5-VOLT REGULATOR

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE C1 AND C2.
3. ☐ MOVE BLUE WIRE AT V6 TO SPRING 38.
4. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
5. ☐ CONNECT SPRING 37 TO V6 (+9V) (BLU WIRE).

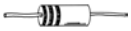
2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. BE SURE THAT NO EXPOSED COMPONENT LEADS TOUCH ONE ANOTHER OR THE 7805. ROTATE THE KNOB OF THE 10K CONSOLE POT (R1) ALL THE WAY TO THE LEFT. PUSH THE POWER SWITCH ON AND SLOWLY ROTATE R1'S KNOB WHILE WATCHING THE METER. COMPARE WHAT YOU SEE WITH THE GRAPH ON PAGE 70. NOTE HOW THE METER READING NEVER EXCEEDS 0.5 MA (5 VOLTS).

BUILD A PRECISION REGULATED LIGHT SOURCE

HIGHLY STABLE LIGHT SOURCES, WHOSE BRIGHTNESS DOES NOT CHANGE SIGNIFICANTLY OVER TIME, HAVE IMPORTANT APPLICATIONS IN SCIENCE AND TECHNOLOGY. YOU WILL BUILD A VERY STABLE REGULATED LIGHT SOURCE BY USING A 7805 TO POWER AN LED.

PARTS YOU WILL NEED

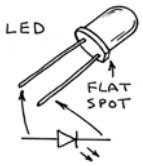


R1-1K (BRN-BLK-RED)

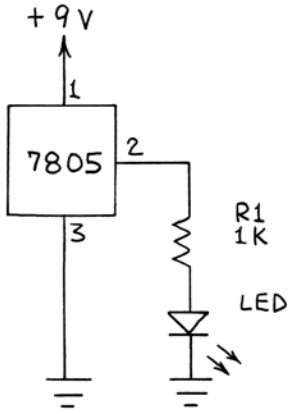
LED-RED OR GREEN LED

THE 7805 REGULATOR HAS AN UNUSUAL PIN NUMBER ARRANGEMENT. <u>ALWAYS REMEMBER THAT THE CENTER PIN IS GROUND.</u>

CIRCUIT DIAGRAM



IT'S OK TO REPLACE R1 AND THE LED WITH ONE OF THE CONSOLE LEDS. THESE LEDS HAVE BUILT-IN SERIES RESISTORS.



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT THE 7805 AT J8 (PIN 1), K8 (PIN 3) AND L8 (PIN 2).
3. ☐ INSERT R1 ACROSS L6 AND T5.
4. ☐ INSERT THE LED ACROSS T1 (ANODE) AND GROUND (CATHODE).
5. ☐ CONNECT J6 TO V6 (+9V) (RED WIRE).
6. ☐ CONNECT K6 TO GROUND (WHT WIRE).

2. TEST THE CIRCUIT

CHECK YOUR WIRING AND PUSH THE POWER SWITCH UP. THE LED WILL GLOW. ITS LIGHT OUTPUT WILL BE TIGHTLY REGULATED AND THEREFORE VERY STABLE.

OPERATIONAL AMPLIFIERS (OP AMPS) AND HOW TO USE THEM

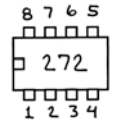
OPERATIONAL AMPLIFIERS OR OP AMPS ARE THE HIGH PERFORMANCE AMPLIFIERS OF THE ELECTRONICS WORLD. THEY HAVE HUNDREDS OF APPLICATIONS. THE OP AMP HAS TWO INPUTS, THE NON-INVERTING INPUT (+) AND THE INVERTING INPUT (-). THE POLARITY OF A SIGNAL APPLIED TO THE NON-INVERTING INPUT IS UNCHANGED AT THE OUTPUT. THE POLARITY OF A SIGNAL APPLIED TO THE INVERTING INPUT IS REVERSED AT THE OUTPUT.

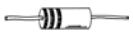
GAIN IS THE DEGREE OF AMPLIFICATION OF AN OP AMP. THE GAIN IS CONTROLLED BY A RESISTOR BETWEEN THE OUTPUT AND THE INVERTING INPUT. THIS RESISTOR IS CALLED A FEEDBACK RESISTOR, SINCE IT FEEDS SOME OF THE OUTPUT BACK TO THE INPUT. A VERY NICE FEATURE OF THE OP AMP IS THAT THE GAIN IS INDEPENDENT OF THE SUPPLY VOLTAGE. OP AMPS CAN AMPLIFY A CONTINUOUS VOLTAGE (AS IN THE CIRCUIT BELOW) OR A FLUCTUATING SIGNAL. WHEN FLUCTUATING SIGNALS ARE AMPLIFIED, A CAPACITOR IS USUALLY PLACED BETWEEN THE SIGNAL SOURCE AND THE OP AMP INPUT.

BUILD A NON-INVERTING AMPLIFIER

YOU WILL USE ONE OP AMP IN A TLC272 TO BUILD A BASIC NON-INVERTING AMPLIFIER. YOU WILL USE THE 100K CONSOLE POT (R3) TO APPLY A VARIABLE VOLTAGE TO THE OP AMP'S INPUT.

PARTS YOU WILL NEED



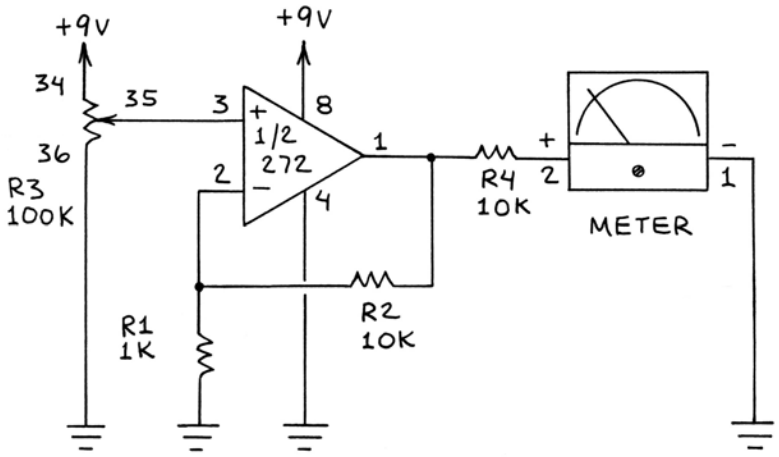


R1-1K (BRN-BLK-RED)
R2, R4-10K (BRN-BLK-ORG)

NON-INVERTING AMPLIFIER GAIN FORMULA:

GAIN = 1 + (R2/R1)

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT TLC272 IC OVER SLOT 3 (PIN 1 AT J15).
3. ☐ INSERT R1 ACROSS K11 AND GROUND.
4. ☐ INSERT R2 ACROSS J13 AND K13.
5. ☐ INSERT R4 ACROSS J14 AND G18.
6. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
7. ☐ CONNECT SPRING 2 TO G20 (BLU WIRE).
8. ☐ CONNECT SPRING 36 TO GROUND (RED WIRE).
9. ☐ CONNECT SPRINGS 35 TO L11 (RED WIRE).
10. ☐ CONNECT SPRING 34 TO V6 (+9V) (BLU WIRE).
11. ☐ CONNECT M11 TO GROUND (WHT WIRE).
12. ☐ CONNECT J20 TO V6 (+9V) (WHT WIRE).

2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. THEN PUSH THE POWER SWITCH UP. ROTATE THE KNOB OF THE 100K CONSOLE POT (R3) ALL THE WAY TO THE LEFT TO REDUCE THE VOLTAGE APPLIED TO THE INPUT OF THE OP AMP. THE METER NEEDLE WILL MOVE TO 0. NOW ROTATE R3 TO THE RIGHT TO INCREASE THE VOLTAGE APPLIED TO THE OP AMP INPUT. THE METER NEEDLE WILL MOVE UPWARD. THIS OPERATION SHOWS THAT THE POLARITY OF THE INPUT OF A NON-INVERTING AMPLIFIER IS UNCHANGED AT THE OUTPUT.

3. TEST THE GAIN FORMULA FOR THE NON-INVERTING AMPLIFIER

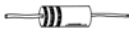
MOVE THE R4 LEAD AT J14 TO L14. ADJUST R3 SO THE METER READS ONE DIVISION (0.02 MA OR, FROM OHMS LAW, 0.2 VOLT). NOW MOVE THE R4 LEAD AT L14 BACK TO J14. THE METER WILL NOW READ 10 DIVISIONS (0.2 MA OR 2 VOLTS). THE GAIN IS THEN 2V/0.2V OR 10, WHICH IS CLOSE TO THE FORMULA (1 + 10,000/1,000 = 11). TIP: TRY THIS TEST USING A MULTIMETER.

BUILD AN INVERTING AMPLIFIER

YOU WILL USE ONE OP AMP IN A TLC272 TO BUILD AN INVERTING AMPLIFIER. YOU WILL INCLUDE A VOLTAGE DIVIDER (R5 AND R6) TO PLACE ABOUT HALF THE SUPPLY VOLTAGE AT THE NON-INVERTING INPUT (PIN 3). THIS WILL CAUSE THE OUTPUT (PIN 1) TO BE SEVERAL VOLTS ABOVE GROUND AND ALLOW THE OUTPUT SIGNAL TO FLUCTUATE ABOVE AND BELOW THIS LEVEL.

PARTS YOU WILL NEED

THE NON-INVERTING AMPLIFIER ON PAGE 72 PLUS:

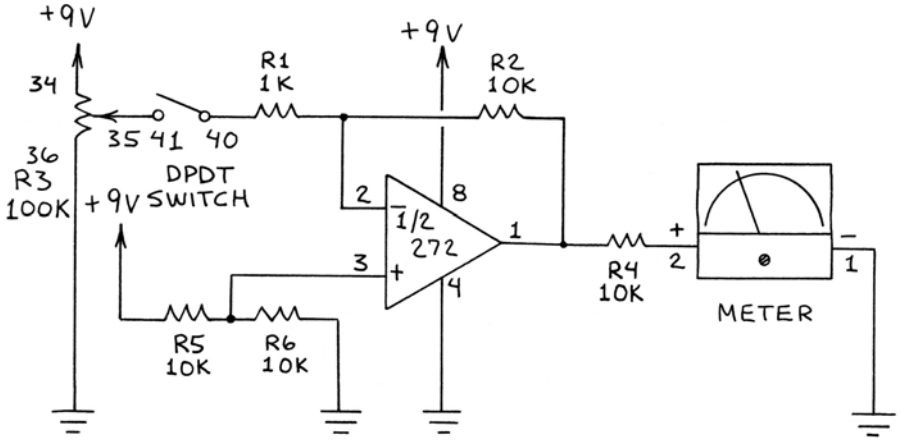


R5, R6–10K (BRN-BLK-ORG)

INVERTING AMPLIFIER GAIN FORMULA:

GAIN = -(R2/R1)

CIRCUIT DIAGRAM



1. MODIFY THE NON-INVERTING AMPLIFIER ON PAGE 72

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE R1 FROM K11 AND GROUND.
3. ☐ INSERT R1 ACROSS K8 AND K11.
4. ☐ REMOVE RED WIRE BETWEEN SPRING 35 AND L11.
5. ☐ CONNECT SPRINGS 35 AND 41 (RED WIRE).
6. ☐ CONNECT SPRING 40 AND K6 (RED WIRE).
7. ☐ INSERT R5 ACROSS L11 AND GROUND.
8. ☐ INSERT R6 ACROSS L14 AND J19.

2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. PUSH THE DPDT SWITCH DOWN AND THE POWER SWITCH UP. NO VOLTAGE IS PRESENT AT THE AMPLIFIER'S INVERTING INPUT, AND THE METER DISPLAYS ABOUT 0.4 MA, WHICH IS EQUIVALENT TO 4 VOLTS. PUSH THE DPDT SWITCH UP TO CONNECT THE VOLTAGE DIVIDER FORMED BY THE 100K CONSOLE POT (R3). ROTATE R3 TO THE LEFT TO REDUCE THE INPUT VOLTAGE, AND THE OUTPUT VOLTAGE WILL INCREASE. ROTATE R3 TO THE RIGHT TO INCREASE THE INPUT VOLTAGE, AND THE OUTPUT VOLTAGE WILL DECREASE. THIS SIMPLE DEMONSTRATION CLEARLY SHOWS THAT THE AMPLIFIER INVERTS THE INPUT VOLTAGE.

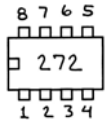
3. TEST THE GAIN FORMULA FOR THE INVERTING AMPLIFIER

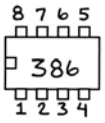
THIS TEST IS BEST DONE WITH A RADIOSHACK MULTIMETER. FIRST, MEASURE THE REFERENCE VOLTAGE AT PIN 3 OF THE OP AMP. IT WILL BE ABOUT 4.5 VOLTS IF YOUR BATTERIES ARE FRESH. ADJUST R3 SO THAT THE INPUT VOLTAGE TO THE OP AMP (SPRING 35) IS 0.1 VOLT BELOW THE OFFSET VOLTAGE. THIS IS THE SAME AS AN INPUT OF -0.1 VOLT. THEN MEASURE THE OUTPUT VOLTAGE AT PIN 1 OF THE OP AMP. A TYPICAL VALUE IS 5.53 VOLTS. SUBTRACT THE REFERENCE VOLTAGE FROM THE OUTPUT VOLTAGE. A TYPICAL RESULT IS 1.03 VOLTS. THE GAIN FOR THESE TYPICAL RESULTS IS 1.03/0.1 = 10.3. YOUR RESULTS MAY VARY. SINCE THE INPUT VOLTAGE IN THIS EXAMPLE IS BELOW (-) THE REFERENCE VOLTAGE, THE GAIN IS -10.3. THIS IS VERY CLOSE TO WHAT THE FORMULA PREDICTS, WHICH IS G = -(R2/R1) OR -10.

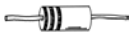
BUILD A SUPER-SENSITIVE OP AMP AUDIO AMPLIFIER (AND LISTEN TO ANTS)

YOU WILL BUILD A VERY HIGH-GAIN AUDIO AMPLIFIER WITH ADJUSTABLE GAIN AND VOLUME. THE AMPLIFIER IS SO POWERFUL THAT SQUEAKING SOUNDS PRODUCED BY ANGRY FIRE ANTS COULD BE EASILY HEARD WHEN THE EARPHONE WAS PLACED ON THEIR MOUND. THE AMPLIFIER USES THE CERAMIC EARPHONE AS A MICROPHONE. ONE OF THE TWO AMPLIFIERS IN A TLC272 DUAL OP AMP SERVES AS A PREAMPLIFIER. AN LM386 SERVES AS A POWER AMPLIFIER FOR DRIVING THE SPEAKER. CONSOLE POTS ARE USED TO CONTROL THE GAIN OF THE PREAMPLIFIER AND THE VOLUME OF THE SPEAKER. A BATTERY-POWERED RADIO IS HANDY FOR INITIAL TESTS.

PARTS YOU WILL NEED

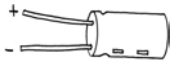






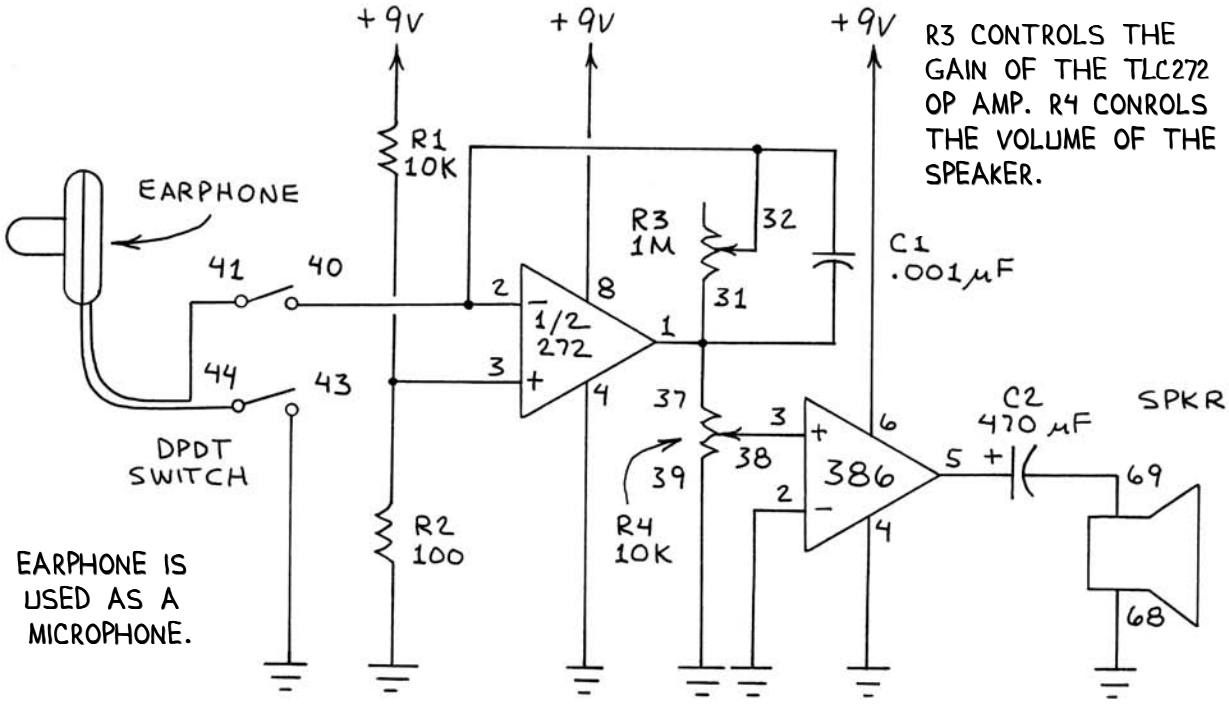
R1-10K (BRN-BLK-ORG)
R2-100 OHMS (BRN-BLK-BRN)

C1-0.001 UF (102)



C2-470 UF

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT TLC272 IC OVER SLOT 3 (PIN 1 AT J15).
3. ☐ INSERT 386 IC OVER SLOT 5 (PIN 1 AT J25).
4. ☐ INSERT R1 ACROSS L14 AND J18.
5. ☐ INSERT R2 ACROSS L12 AND GROUND.
6. ☐ INSERT C1 ACROSS J12 AND K12.
7. ☐ INSERT C2 ACROSS M28 (+) AND S28 (-).
8. ☐ CONNECT M11 TO GROUND (WHT WIRE).
9. ☐ CONNECT J20 TO V6 (+9V) (WHT WIRE).
10. ☐ CONNECT M21 TO GROUND (WHT WIRE).
11. ☐ CONNECT K21 TO GROUND (WHT WIRE).
12. ☐ CONNECT L30 TO V6 (+9V) (WHT WIRE).
13. ☐ CONNECT SPRING 68 TO GROUND (BLU WIRE).
14. ☐ CONNECT SPRING 69 TO S30 (BLU WIRE).
15. ☐ CONNECT SPRING 31 TO J11 (RED WIRE).
16. ☐ CONNECT SPRING 32 TO K11 (RED WIRE).
17. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
18. ☐ CONNECT SPRING 38 TO L21 (BLU WIRE).
19. ☐ CONNECT SPRING 37 TO J13 (BLU WIRE).
20. ☐ CONNECT SPRING 40 TO K14 (BLU WIRE).
21. ☐ CONNECT SPRING 43 TO GROUND (WHT WIRE).
22. ☐ CONNECT ONE PHONE LEAD TO SPRING 41.
23. ☐ CONNECT SECOND PHONE LEAD TO SPRING 44.

2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. ROTATE THE KNOBS OF BOTH THE 10K (R4) AND 1M (R3) CONSOLE POTS ALL THE WAY TO THE LEFT. THIS MAXIMIZES THE GAIN OF THE PREAMPLIFIER STAGE AND MINIMIZES THE SPEAKER VOLUME. PUSH THE DPDT SWITCH UP TO CONNECT THE EARPHONE (MICROPHONE) TO THE PREAMPLIFIER. PUSH THE POWER SWITCH ON.

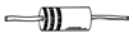
IF A RADIO IS AVAILABLE, TUNE IT TO A STATION AND ADJUST THE VOLUME FOR A QUIET SOUND. USE A RUBBER BAND OR TAPE TO TEMPORARILY ATTACH THE MICROPHONE TO THE RADIO'S SPEAKER. THEN PLACE THE RADIO IN A CLOSED DRAWER. SLOWLY ROTATE THE 10K CONSOLE POT'S KNOB TO THE RIGHT. AT SOME POINT YOU WILL HEAR THE RADIO SOUND FROM THE CONSOLE SPEAKER. EXPERIMENT WITH THE AMPLIFIER BY INCREASING THE VOLUME OF THE SPEAKER (R4) AND REDUCING THE GAIN OF THE PREAMPLIFIER (R3).

IF THE MICROPHONE IS NEAR THE CONSOLE WHEN THE AMPLFIER IS ON, YOU MAY HEAR A LOUD SQUEAL. THIS IS OSCILLATION CAUSED BY FEEDBACK WHEN SOME OF THE OUTPUT SIGNAL IS DETECTED BY THE MICROPHONE AND REAMPLIFIED. MOVE THE MICROPHONE AWAY FROM THE CONSOLE OR TURN THE SPEAKER VOLUME DOWN (R4). IF THE SOUND QUALITY SEEMS HARSH, ADD A SECOND C1 ACROSS THE FIRST C1.

ADD A SIGNAL STRENGTH INDICATOR TO THE SUPER-SENSITIVE AMPLIFIER ON PAGE 74

YOU WILL ADD AN LED SIGNAL INDICATOR TO THE SUPER-SENSITIVE AUDIO AMPLIFIER ON PAGE 74. THE INDICATOR CIRCUIT WILL USE THE UNUSED SECOND OP AMP IN THE TLC272.

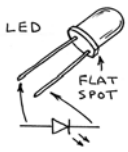
PARTS YOU WILL NEED



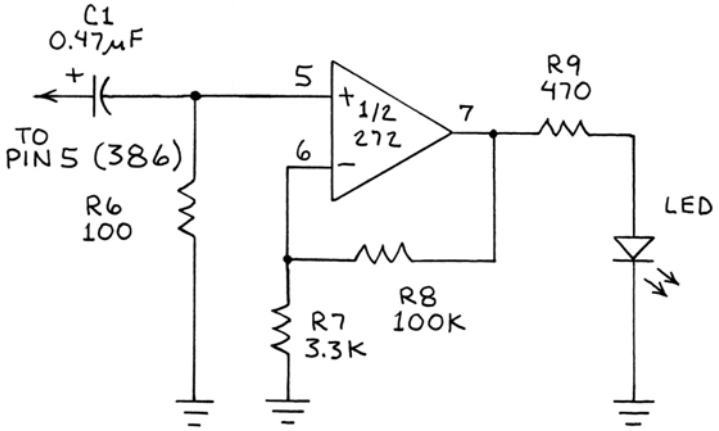
R6-100 OHMS (BRN-BLK-BRN)
R7-3.3K (ORG-ORG-RED)
R8-100K (BRN-BLK-YEL)
R9-470 OHMS (YEL-VIO-BRN)

C1-0.47 UF (SPREAD LEADS SO C1 WILL FIT BETWEEN THE TWO ICS)

LED-GREEN LED



CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT C1 ACROSS M27 (+) AND M20 (-).
3. ☐ INSERT R6 ACROSS M18 AND GROUND.
4. ☐ INSERT R7 ACROSS L17 AND GROUND.
5. ☐ INSERT R8 ACROSS K18 AND L18.
6. ☐ INSERT R9 ACROSS K20 AND T20.
7. ☐ INSERT LED ACROSS T18 (ANODE) AND GROUND (CATHODE).

2. TEST THE CIRCUIT

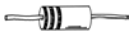
THE BREADBOARD IS NOW PRETTY CROWDED, SO MAKE SURE NONE OF THE COMPONENT WIRES ARE TOUCHING ONE ANOTHER. SET THE AMPLIFIER UP AS DESCRIBED ABOVE (SEE 2. TEST THE CIRCUIT). THEN PUSH THE POWER SWITCH ON. THE LED WILL FLICKER IN RESPONSE TO SOUND. LOUDER SIGNALS WILL CAUSE BRIGHTER FLICKERING. INCREASE THE VOLUME TO INCREASE THE LED BRIGHTNESS. IF THE SOUND FROM THE SPEAKER IS ANNOYINGLY LOUD, DISCONNECT ONE OF THE SPEAKER WIRES WHILE YOU TEST THE LED INDICATOR.

ADD A SOUND-LEVEL METER TO THE SUPER-SENSITIVE AMPLIFIER ON PAGE 74

YOU WILL CONNECT THE METER TO THE SUPER-SENSITIVE AMPLIFIER SO THAT YOU CAN OBSERVE THE SIGNAL LEVEL. YOU WILL ALSO BE ABLE TO SEE THE FLUCTUATIONS IN THE SIGNAL. BE SURE TO FOLLOW INSTRUCTIONS CAREFULLY TO AVOID DAMAGING THE METER.

PARTS YOU WILL NEED

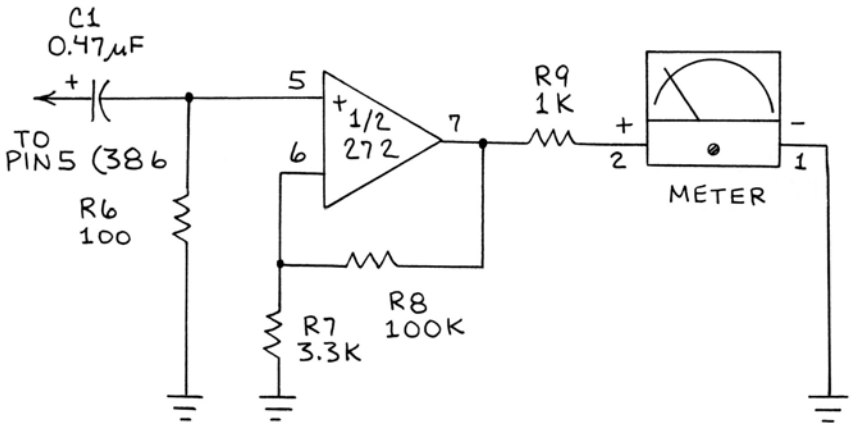
LED SIGNAL INDICATOR (P. 75) PLUS:



R9-1K (BRN-BLK-RED)

COMPARE THIS CIRCUIT WITH THE NEARLY IDENTICAL LED VERSION ON PAGE 75. R9 IN THIS CIRCUIT HAS A HIGHER RESISTANCE TO PROTECT THE METER FROM EXCESSIVE CURRENT.

CIRCUIT DIAGRAM



1. MODIFY THE LED SIGNAL STRENGTH INDICATOR ON PAGE 75

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE THE LED.
3. ☐ REMOVE OLD R9.
4. ☐ INSERT NEW R9 ACROSS K20 AND T20.
5. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
6. ☐ CONNECT SPRING 2 TO T18 (BLU WIRE).

2. TEST THE CIRCUIT

THE MODIFIED CIRCUIT IS CROWDED, SO MAKE SURE NONE OF THE COMPONENT WIRES ARE TOUCHING ONE ANOTHER. IT IS VERY IMPORTANT TO SET THE AMPLIFIER UP AS PREVIOUSLY DESCRIBED. THIS WILL PROVIDE MAXIMUM PROTECTION FOR THE METER. THEN PUSH THE POWER SWITCH ON.

PLACE THE MICROPHONE NEXT TO A SIGNAL SOURCE SUCH AS A SMALL TRANSISTOR RADIO. THEN SLOWLY INCREASE THE SPEAKER VOLUME BY ROTATING THE 10K CONSOLE POT (R4). THE METER NEEDLE SHOULD BEGIN FLUCTUATING IN STEP WITH THE SOUND FROM THE RADIO. WITH THE VALUES SHOWN IN THE CIRCUIT DIAGRAM, THE METER NEEDLE OCCASIONALLY SWINGS FULL SCALE WHEN THE SIGNAL IS QUITE LOUD. BE SURE TO REDUCE THE VOLUME IF THE METER NEEDLE GOES OFF SCALE. OTHERWISE THE METER MAY BE DAMAGED.

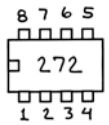
3. GOING FURTHER

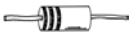
YOU CAN USE THE SOUND-LEVEL METER TO STUDY THE DISTRIBUTION OF SOUND WAVES FROM THE BUZZER. THE FREQUENCY OF THE TONE EMITTED BY THE BUZZER IS VERY CLEAN AND NARROW. THIS MEANS THE SOUND WAVES CAN INTERFERE WITH THEMSELVES WHEN REFLECTED FROM SMOOTH SURFACES. CONSTRUCTIVE INTERFERENCE OF THE SOUND WAVES EMITTED BY THE BUZZER AND REFLECTED FROM SMOOTH SURFACES WILL CAUSE AREAS WHERE THE SOUND IS ESPECIALLY INTENSE (HOT SPOTS). DESTRUCTIVE INTERFERENCE OF THE SOUND WAVES WILL CAUSE AREAS WHERE THE SOUND IS LESS INTENSE (COLD SPOTS). YOU CAN FIND THESE AREAS BY MOVING THE MICROPHONE (EARPHONE) AROUND WHILE WATCHING THE METER NEEDLE. FIRST, REMOVE THE BLUE SPEAKER WIRE BETWEEN SPRING 69 AND T30. THEN USE BLUE WIRES TO CONNECT SPRING 67 TO GROUND AND SPRING 66 TO V6 (+9V). MOVE THE EARPHONE AROUND AND WATCH THE METER NEEDLE MOVE SLIGHTLY UP AT HOT SPOTS AND DOWN AT COLD SPOTS. ADJUST THE 10K CONSOLE POT (R4) FOR BEST RESULTS.

BUILD A LIGHT-SENSITIVE AUDIO OSCILLATOR

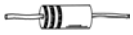
YOU WILL USE ONE OF THE OP AMPS IN A TLC272 TO BUILD AN OSCILLATOR THAT RESPONDS TO LIGHT. WHEN THE LIGHT IS BRIGHT, THE FREQUENCY IS HIGH. WHEN THE LIGHT IS LOW, SO IS THE FREQUENCY. THIS PROJECT IS IMPORTANT FOR OTHER REASONS. IT DEMONSTRATES THAT THE TLC272 WORKS WELL WHEN POWERED BY ONLY 3 VOLTS. AND IT SHOWS THAT A TRANSFORMER PLUS SPEAKER CAN OFTEN PROVIDE PLENTY OF SOUND WITHOUT HAVING TO USE A POWER AMPLIFIER LIKE THE LM386. THE 386 IS SMALLER, AND IT'S VOLUME CAN BE CONTROLLED. BUT IT USES MORE POWER THAN THE TRANSFORMER.

PARTS YOU WILL NEED





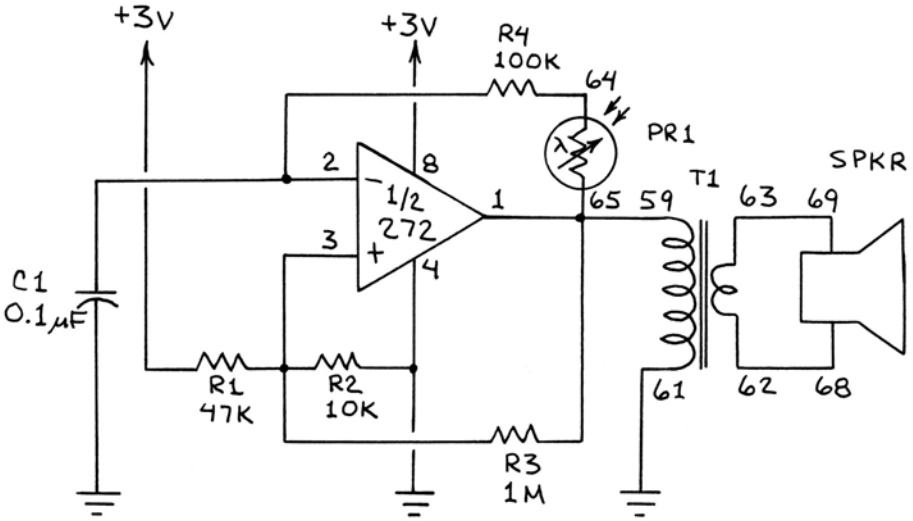
R1-47K (YEL-VIO-ORG)
R2-10K (BRN-BLK-ORG)



R3-1M (BRN-BLK-GRN)
R4-100K (BRN-BLK-YEL)

C1-0.1 UF (104)

CIRCUIT DIAGRAM



THIS CIRCUIT IS EASY TO MODIFY. HERE ARE SOME VARIATIONS YOU CAN TRY:

1. REPLACE THE TRANSFORMER WITH A 386 POWER AMPLIFIER. USE A CAPACITOR BETWEEN THE 272 OUTPUT (PIN 1) AND THE 386.

2. CHANGE THE VALUE OF C1 TO SEE WHAT HAPPENS.

3. REPLACE R3 WITH THE 1M CONSOLE POT TO MAKE THE CIRCUIT ADJUSTABLE.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT TLC272 IC OVER SLOT 3 (PIN 1 AT J15).
3. ☐ INSERT R2 ACROSS L14 AND GROUND.
4. ☐ INSERT R1 ACROSS L13 AND J18.
5. ☐ INSERT R3 ACROSS J11 AND L11 (PUSH AGAINST THE BREADBOARD TO MAKE ROOM FOR ADDING OTHER PARTS).
6. ☐ INSERT R4 ACROSS K14 AND C16.
7. ☐ INSERT C1 ACROSS K12 AND M12.
8. ☐ CONNECT M11 TO GROUND (WHT WIRE).
9. ☐ CONNECT J20 TO V2 (+3V) (RED WIRE).
10. ☐ CONNECT SPRING 64 TO C20 (BLU WIRE).
11. ☐ CONNECT SPRING 65 TO J14 (BLU WIRE).
12. ☐ CONNECT SPRING 59 TO J12 (BLU WIRE).
13. ☐ CONNECT SPRING 61 TO GROUND (RED WIRE).
14. ☐ CONNECT SPRINGS 63 AND 69 (RED WIRE).
15. ☐ CONNECT SPRINGS 62 AND 68 (RED WIRE).

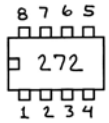
2. TEST THE CIRCUIT

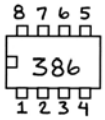
CHECK YOUR WIRING FOR ERRORS. PAY SPECIAL ATTENTION TO THE RESISTORS AND CAPACITORS AND BE SURE NONE OF THEIR EXPOSED LEADS TOUCH ONE ANOTHER. PLACE A FINGER OVER THE PHOTORESISTOR AND PUSH THE POWER SWITCH UP. YOU WILL HEAR A TONE WITH A FREQUENCY OF A FEW HUNDRED HERTZ. REMOVE YOUR FINGER, AND THE FREQUENCY OF THE TONE WILL RISE TO A FEW THOUSAND HERTZ. EXPERIMENT WITH DIFFERENT LIGHT LEVELS TO SEE HOW THE TONE IS AFFECTED. MOVE THE RED WIRE AT V2 TO HIGHER VOLTAGES. WHAT HAPPENS?

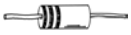
BUILD A PERCUSSION INSTRUMENT SYNTHESIZER

A PERCUSSION MUSICAL INSTRUMENT IS ONE THAT IS STRUCK BY SOMETHING. DRUMS, BELLS AND CYMBALS ARE PERCUSSION INSTRUMENTS. THE AMPLITUDE OF A PERCUSSION SOUND DECLINES WITH TIME, WHICH CAN RANGE FROM A FRACTION OF A SECOND TO SEVERAL SECONDS. CAPACITORS ARE A KEY COMPONENT IN ELECTRONIC CIRCUITS THAT SIMULATE PERCUSSION SOUNDS. THIS IS BECAUSE THE VOLTAGE STORED IN A CAPACITOR CAN BE MADE TO DISCHARGE OVER TIME MUCH THE SAME WAY A PERCUSSION SOUND DECAYS. YOU WILL BUILD A PERCUSSION SYNTHESIZER THAT USES ONE OP AMP IN A TLC272 AS AN OSCILLATOR THAT CAN BE ADJUSTED TO JUST BELOW THE OSCILLATION POINT. A BRIEF INPUT SIGNAL FROM A PUSH-BUTTON SWITCH WILL CAUSE THE CIRCUIT TO OSCILLATE FOR A BRIEF TIME, THEREBY CREATING A PERCUSSION EFFECT. THE SOUND IS AMPLIFIED TO A RESPECTABLE LEVEL BY AN LM386 POWER AMPLIFIER.

PARTS YOU WILL NEED

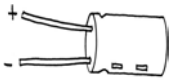






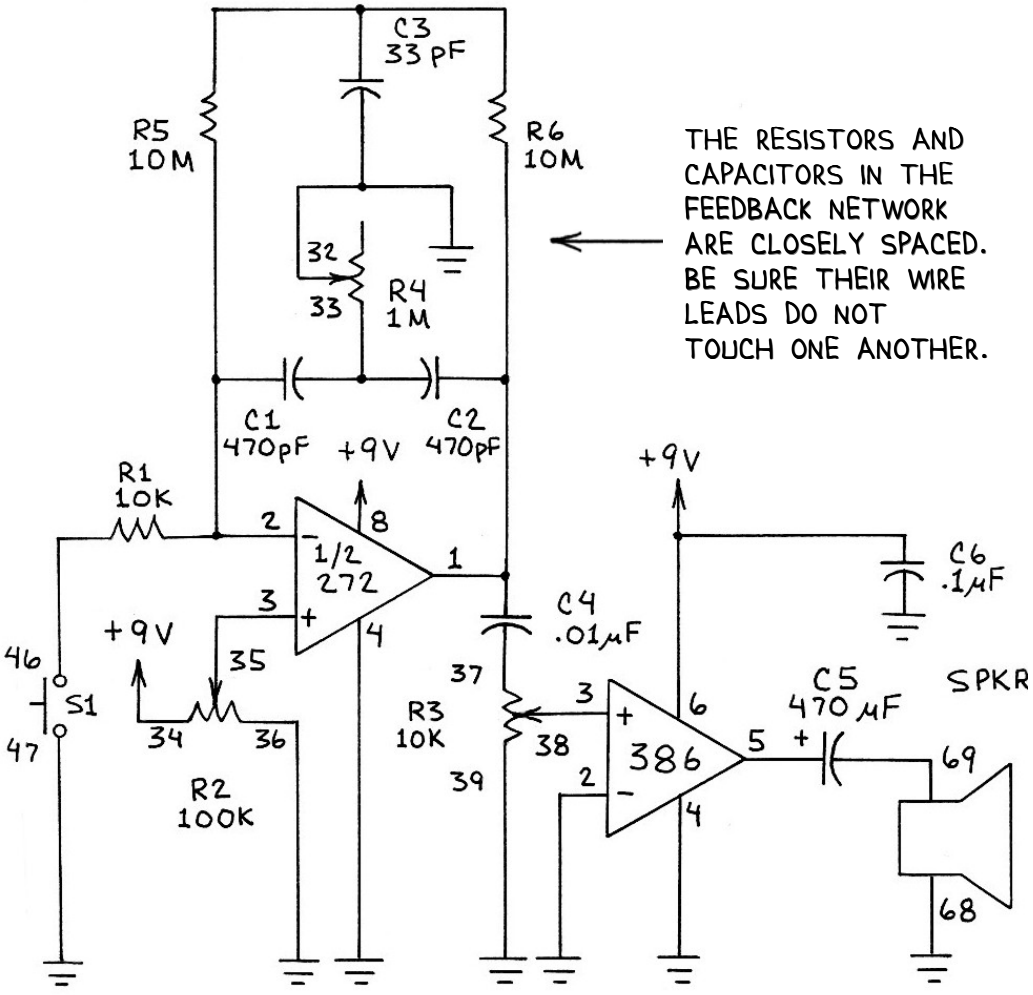
R1-10K (BRN-BLK-ORG)
R5, R6-10M (BRN-BLK-BLU)

C1, C2-470 PF (471)
C3-33 PF
C4-0.01 UF (103)
C6-0.1 UF (104)



C5-470 UF

CIRCUIT DIAGRAM



THE RESISTORS AND CAPACITORS IN THE FEEDBACK NETWORK ARE CLOSELY SPACED. BE SURE THEIR WIRE LEADS DO NOT TOUCH ONE ANOTHER.

CONSOLE POTS:

THE 10K POT (R3) CONTROLS THE SPEAKER VOLUME.

THE 100K POT (R2) LETS YOU ADJUST THE BIAS TO THE NON-INVERTING INPUT (+) OF THE OP AMP TO SOMEWHERE ABOVE GROUND (0 VOLT) SO THAT A FLUCTUATING SIGNAL CAN RIDE ABOVE AND BELOW THE PRESET OUTPUT VOLTAGE.

THE 1M POT (R4) CONTROLS THE OSCILLATION CAUSED BY FEEDBACK FROM THE CAPACITORS AND RESISTORS IN THE NETWORK BETWEEN THE OUTPUT AND THE INVERTING INPUT OF THE OP AMP.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT TLC272 IC OVER SLOT 3 (PIN 1 AT J15).
3. ☐ INSERT 386 IC OVER SLOT 5 (PIN 1 AT J25).
4. ☐ CONNECT M11 TO GROUND (WHT WIRE).
5. ☐ CONNECT J20 TO V6 (+9V) (RED WIRE).
6. ☐ INSERT R1 ACROSS K9 AND K11.
7. ☐ INSERT C4 ACROSS J9 AND J11.
8. ☐ INSERT R5 ACROSS K12 AND T12.
9. ☐ INSERT R6 ACROSS J14 AND T14.
10. ☐ INSERT C1 ACROSS G13 AND K13.
11. ☐ INSERT C2 ACROSS G14 AND J13.
12. ☐ INSERT C3 ACROSS T13 AND GROUND.
13. ☐ CONNECT M21 TO GROUND (WHT WIRE).
14. ☐ CONNECT K21 TO GROUND (WHT WIRE).
15. ☐ CONNECT L30 TO V6 (+9V) (WHT WIRE).
16. ☐ INSERT C5 ACROSS M28 (+) AND S28 (−).
17. ☐ INSERT C6 ACROSS L27 AND M24.
18. ☐ CONNECT SPRING 33 TO G11 (RED WIRE).
19. ☐ CONNECT SPRING 32 TO GROUND (RED WIRE).
20. ☐ CONNECT SPRING 34 TO V6 (+9V) (BLU WIRE).
21. ☐ CONNECT SPRING 35 TO L11 (RED WIRE).
22. ☐ CONNECT SPRING 36 TO GROUND (RED WIRE).
23. ☐ CONNECT SPRING 37 TO J6 (BLU WIRE).
24. ☐ CONNECT SPRING 38 TO L21 (BLU WIRE).
25. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
26. ☐ CONNECT SPRING 46 TO K6 (RED WIRE).
27. ☐ CONNECT SPRING 47 TO GROUND (RED WIRE).
28. ☐ CONNECT SPRING 68 TO GROUND (BLU WIRE).
29. ☐ CONNECT SPRING 69 TO S30 (BLU WIRE).

2. TEST THE CIRCUIT

CHECK THE CIRCUIT FOR WIRING ERRORS. THE TLC272 PORTION OF THIS CIRCUIT IS FAIRLY CROWDED, SO BE SURE NONE OF THE COMPONENT WIRES TOUCH ONE ANOTHER. THEN ROTATE THE KNOB OF THE 10K CONSOLE POT (R3) ALL THE WAY TO THE RIGHT FOR MAXIMUM VOLUME. ROTATE THE KNOBS OF THE 100K (R2) AND 1M (R4) CONSOLE POTS TO THEIR MIDPOINTS. THEN PUSH THE POWER SWITCH ON.

ROTATE THE 1M CONSOLE POT (R4) LEFT OR RIGHT UNTIL THE SPEAKER <u>JUST BEGINS</u> TO SQUEAL. NOW SLOWLY ROTATE THE 1M POT TO THE RIGHT UNTIL THE SOUND <u>JUST STOPS</u>. PRESS S1, AND THE SPEAKER WILL EMIT A SOUND LIKE A PLUCKED BASS STRING OR A DRUM. ROTATE THE 1M POT TO THE RIGHT TO SHORTEN THE SOUND. ROTATE THE 1M POT TO THE LEFT TO STRETCH THE SOUND. ADJUST THE 100K POT TO ALTER THE TONE OF THE SOUND.

3. GOING FURTHER

YOU CAN EXPERIMENT WITH THE FEEDBACK COMPONENTS IN THIS CIRCUIT TO ALTER THE KINDS OF SOUNDS IT MAKES. YOU CAN ALSO USE THE CIRCUIT TO SHOW THAT SOME SEMICONDUCTOR PARTS HAVE CAPACITANCE. WE'LL DO THIS BY SUBSTITUTING VARIOUS COMPONENTS FOR C3 (33 PF). THE CIRCUIT WILL WORK WITHOUT C3 BUT NOT AS WELL. REMOVE C3 FROM ACROSS T13 AND GROUND AND TRY THESE REPLACEMENTS TO RESTORE THE SOUND:

1. INSERT THE GREEN LED ACROSS T13 (CATHODE) AND GROUND (ANODE). PRESS S1 AND THE CIRCUIT WILL EMIT A DRUM SOUND. THIS DEMONSTRATES THAT THE DIODE JUNCTION OF THE LED HAS CAPACITANCE.

2. INSERT A SILICON DIODE ACROSS T13 (CATHODE) AND GROUND (ANODE). PRESS S1 AND THE CIRCUIT WILL EMIT A DRUM SOUND. THIS SHOWS THAT THE DIODE JUNCTION HAS CAPACITANCE. VARACTORS ARE DIODES ESPECIALLY DESIGNED TO BE USED AS TUNABLE CAPACITORS.

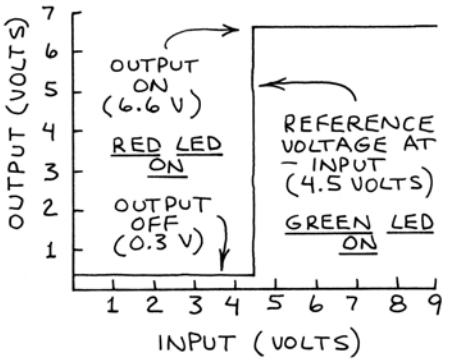
3. WRAP TWO YELLOW CONNECTION WIRES TIGHTLY TOGETHER. INSERT THE TWO WIRES AT ONE END OF THIS PAIR ACROSS T13 AND GROUND. PRESS S1 AND THE SPEAKER WILL EMIT A DRUM SOUND. YOU HAVE MADE A CAPACITOR FROM THE TWO WIRES. ADJUST THE 10M POT FOR BEST RESULTS. TRY THIS WITH A PAIR OF BLUE OR RED WIRES. WHAT HAPPENS?

COMPARATORS AND HOW TO USE THEM

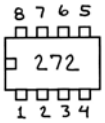
WHEN AN OP AMP IS USED WITHOUT A FEEDBACK RESISTOR, ITS OUTPUT WILL SWING FROM ONE EXTREME TO THE OTHER FOR A TINY CHANGE IN INPUT VOLTAGE. THIS PERMITS OP AMPS TO COMPARE TWO DIFFERENT VOLTAGES AND SWITCH ON OR OFF ACCORDINGLY.

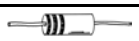
USE AN OP AMP TO BUILD A BASIC VOLTAGE COMPARATOR

YOU WILL USE ONE OP AMP IN A TLC272 AS A COMPARATOR. THE INVERTING INPUT (-) OF THE OP AMP IS CONNECTED TO HALF THE SUPPLY VOLTAGE USING A VOLTAGE DIVIDER (R1 AND R2 BELOW). THIS IS THE REFERENCE VOLTAGE. WHEN THE VOLTAGE AT THE NON-INVERTING INPUT (+) IS BELOW THE REFERENCE VOLTAGE, THE OP AMP OUTPUT IS NEAR GROUND. WHEN THE INPUT VOLTAGE EXCEEDS THE REFERENCE VOLTAGE, THE OP AMP TURNS FULL ON. A POT CAN BE SUBSTITUTED FOR R1 AND R2 TO PROVIDE AN ADJUSTABLE REFERENCE VOLTAGE.



PARTS YOU WILL NEED



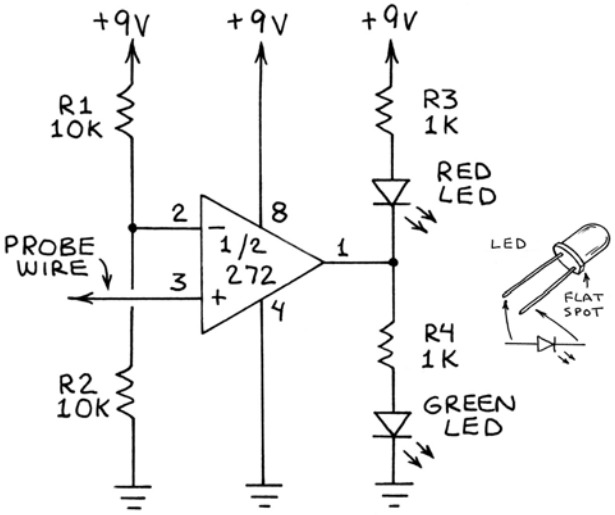


R1, R2-10K (BRN-BLK-ORG)
R3, R4-1K (BRN-BLK-RED)

RED LED

GREEN LED

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT TLC272 IC OVER SLOT 3 (PIN 1 AT J15).
3. ☐ INSERT R1 ACROSS K14 AND J17.
4. ☐ INSERT R2 ACROSS K13 AND GROUND.
5. ☐ INSERT R3 ACROSS H15 AND J18.
6. ☐ INSERT R4 ACROSS J11 AND T11.
7. ☐ INSERT RED LED ACROSS H12 (ANODE) AND J12 (CATHODE).
8. ☐ INSERT GREEN LED ACROSS T12 (ANODE) AND GROUND (CATHODE).
9. ☐ CONNECT M11 TO GROUND (WHT WIRE).
10. ☐ CONNECT J20 TO V6 (+9V) (RED WIRE).
11. ☐ INSERT A BLUE VERTICAL PROBE WIRE AT L12.

2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. THEN PUSH THE POWER SWITCH UP. ONE OF THE LEDS WILL GLOW. TOUCH THE EXPOSED END OF THE BLUE PROBE WIRE TO V6 (+9V) AND ONLY THE GREEN LED WILL GLOW. THE GREEN LED WILL ALSO GLOW WHEN YOU TOUCH THE PROBE TO V5 (7.5V) AND V4 (6V). THE RED LED WILL GLOW WHEN THE PROBE WIRE IS TOUCHED TO V1 (1.5V) AND V2 (+3V). THE FRESHNESS OF YOUR BATTERIES DETERMINES WHICH LED GLOWS WHEN THE PROBE IS TOUCHED TO V4 (4.5V). FRESH BATTERIES WILL CAUSE THE RED LED TO GLOW. OTHERWISE THE GREEN LED WILL GLOW.

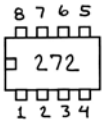
3. GOING FURTHER

SWITCH THE CONNECTIONS TO PINS 2 AND 3 OF THE OP AMP AND REPEAT THE TEST PROCEDURE ABOVE. WHAT HAPPENS TO THE LEDS? CAN YOU EXPLAIN WHY?

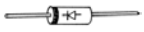
BUILD A VOLTAGE SENSING WINDOW COMPARATOR

YOU WILL USE BOTH OP AMPS IN A TLC272 TO MAKE A WINDOW COMPARATOR THAT INDICATES WHEN A DESIRED INPUT VOLTAGE IS PRESENT AND WHEN THE INPUT IS BELOW OR ABOVE THE DESIRED VOLTAGE. YOU WILL USE POTS TO SET ALL THREE VOLTAGES. IN THE REAL WORLD, THE INPUT VOLTAGE (FROM R2, BELOW) MIGHT COME FROM AN EXTERNAL SENSOR.

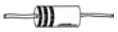
PARTS YOU WILL NEED



Q1-9014 NPN

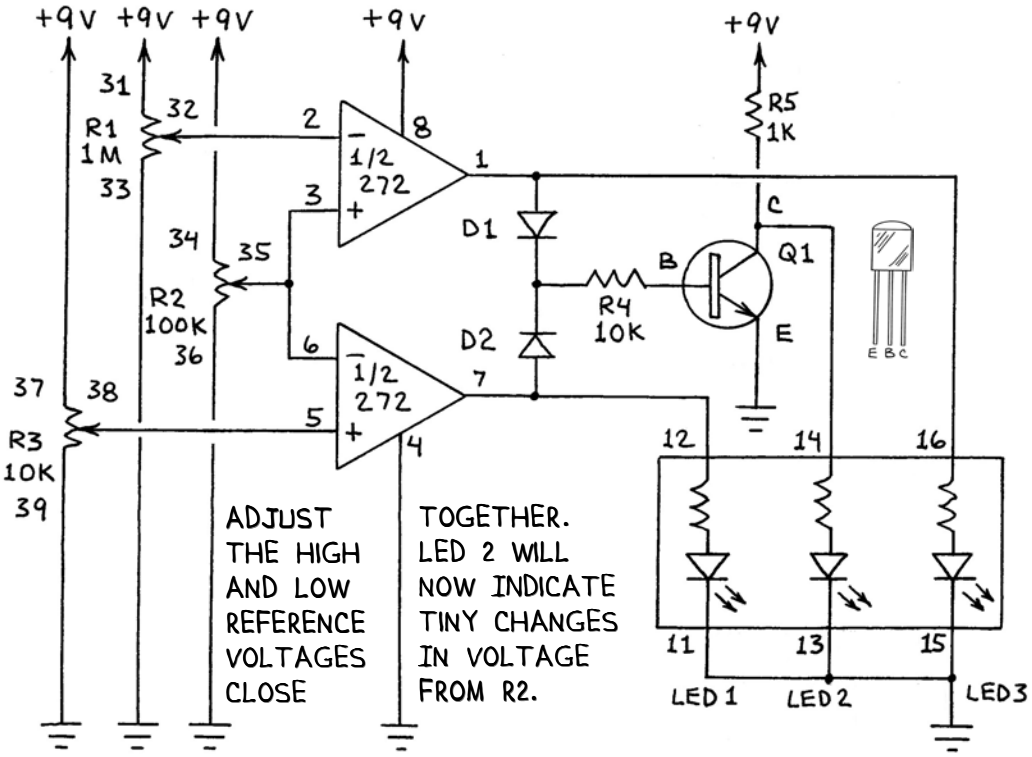


D1, D2-1N4148



R4-10K (BRN-BLK-ORG)
R5-1K (BRN-BLK-RED)

CIRCUIT DIAGRAM



2. TEST THE CIRCUIT

CHECK FOR ERRORS. THEN SET THE HIGH AND LOW REFERENCE VOLTAGES: ROTATE THE 1M CONSOLE POT (R1) MOST, BUT NOT ALL, OF THE WAY RIGHT FOR HIGH VOLTAGE. ROTATE THE 10K CONSOLE POT (R3) MOST, BUT NOT ALL, OF THE WAY LEFT FOR LOW VOLTAGE. PUSH THE POWER SWITCH UP. THEN ROTATE THE 100K CONSOLE POT (R2) TO LEFT. LED 1 WILL GLOW. ROTATE R2 TO RIGHT. LED 3 WILL GLOW. IN BETWEEN, LED 2 WILL GLOW. ROTATE R2 BACK AND FORTH AND THE LEDS WILL GLOW IN SEQUENCE. A VERY COOL CIRCUIT.

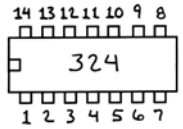
1. BUILD THE CIRCUIT

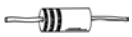
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT TLC272 IC OVER SLOT 3 (PIN 1 AT J15).
3. ☐ INSERT Q1 AT F18 (E), D18 (B) AND B18 (C).
4. ☐ INSERT D1 ACROSS J12 (ANODE) AND D12 (CATHODE).
5. ☐ INSERT D2 ACROSS K17 (ANODE) AND D13 (CATHODE).
6. ☐ INSERT R4 ACROSS D15 AND D16.
7. ☐ INSERT R5 ACROSS B19 AND J19.
8. ☐ CONNECT L14 TO L17 (WHT WIRE).
9. ☐ CONNECT M11 TO GROUND (WHT WIRE).
10. ☐ CONNECT F20 TO GROUND (RED WIRE).
11. ☐ CONNECT J20 TO V6 (+9) (RED WIRE).
12. ☐ CONNECT SPRING 33 TO GROUND (RED WIRE).
13. ☐ CONNECT SPRING 36 TO GROUND (RED WIRE).
14. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
15. ☐ CONNECT SPRING 32 TO K11 (RED WIRE).
16. ☐ CONNECT SPRING 35 TO L11 (RED WIRE).
17. ☐ CONNECT SPRING 38 TO M17 (BLU WIRE).
18. ☐ CONNECT SPRINGS 31 AND 34 (RED WIRE).
19. ☐ CONNECT SPRINGS 34 AND 37 (RED WIRE).
20. ☐ CONNECT SPRING 31 TO V6 (+9V) (BLU WIRE).
21. ☐ CONNECT SPRINGS 11 AND 13 (WHT WIRE).
22. ☐ CONNECT SPRINGS 13 AND 15 (WHT WIRE).
23. ☐ CONNECT SPRING 15 TO GROUND (BLU WIRE).
24. ☐ CONNECT SPRING 12 TO K20 (RED WIRE).
25. ☐ CONNECT SPRING 14 TO B16 (RED WIRE).
26. ☐ CONNECT SPRING 16 TO J11 (RED WIRE).

BUILD AN EXPERIMENTAL OP AMP AUDIO OSCILLATOR

YOU WILL USE ONE OF THE FOUR OP AMPS IN A 324 QUAD OP AMP TO BUILD A SIMPLE AUDIO OSCILLATOR THAT DRIVES A SPEAKER. YOU CAN USE THE CIRCUIT AS SHOWN TO CREATE MUSICAL TONES. OR YOU CAN EXPERIMENT WITH THE CIRCUIT TO CREATE A RANGE OF UNUSUAL TONES. YOU CAN EVEN MAKE THE CIRCUIT RESPOND TO LIGHT.

PARTS YOU WILL NEED

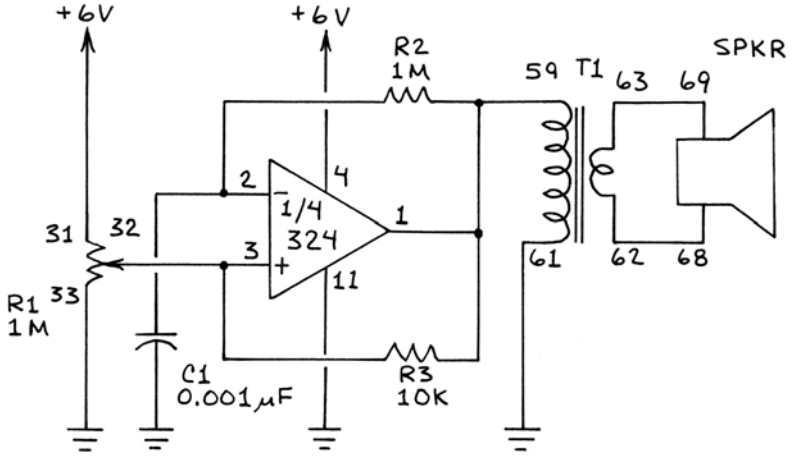




R2–1M (BRN–BLK–GRN)
R3–10K OHMS (BRN–BLK–ORG)

C1–0.001 UF (102)

CIRCUIT DIAGRAM



NOTE THAT THE POWER SUPPLY PINS OF THE 324 ARE LOCATED AT THE CENTER OF THE IC AND NOT AT THE CORNERS. TO AVOID DAMAGING THE 324, BE SURE THESE PINS ARE CONNECTED CORRECTLY.

FOR MORE SOUND, REPLACE THE TRANSFORMER WITH A 386 POWER AMPLIFIER. FOR DETAILS, SEE ANY OF THE PREVIOUS CIRCUITS THAT USE THE 386.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 324 IC OVER SLOT 3 (PIN 1 AT H15).
3. ☐ INSERT R2 ACROSS H11 AND I11.
4. ☐ INSERT R3 ACROSS H12 AND J12.
5. ☐ INSERT C1 ACROSS I14 AND K17.
6. ☐ CONNECT K20 TO GROUND (WHT WIRE).
7. ☐ CONNECT K13 TO V4 (+6V) (WHT WIRE).
8. ☐ CONNECT SPRING 33 TO GROUND (RED WIRE).
9. ☐ CONNECT SPRING 32 TO J11 (RED WIRE).
10. ☐ CONNECT SPRING 31 TO V4 (+6V) (BLU WIRE).
11. ☐ CONNECT SPRING 61 TO GROUND (RED WIRE).
12. ☐ CONNECT SPRING 59 TO H14 (BLU WIRE).
13. ☐ CONNECT SPRINGS 62 AND 68 (RED WIRE).
14. ☐ CONNECT SPRINGS 63 AND 69 (RED WIRE).

2. TEST THE CIRCUIT

THE 324 MAY BE DAMAGED IF YOU CONNECT THE POWER SUPPLY PINS INCORRECTLY. SO CHECK TO MAKE SURE YOU HAVE MADE NO ERRORS. BE SURE THAT BARE COMPONENT LEADS DO NOT TOUCH ONE ANOTHER. PUSH THE POWER SWITCH ON, AND YOU WILL HEAR A TONE FROM THE SPEAKER. CHANGE THE FREQENCY OF THE TONE BY ROTATING THE 1M CONSOLE POT (R1).

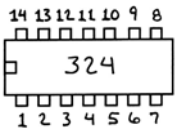
2. GOING FURTHER

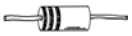
YOU CAN HAVE LOTS OF FUN WITH THIS CIRCUIT. REPLACE C1 WITH A 0.1 (104) CAPACITOR. THE TONE WILL BECOME A SERIES OF CLICKS. REPLACE C1 WITH THE RED LED (ANODE AT K17 AND CATHODE AT I14). SWEEP A FLASHLIGHT BACK AND FORTH ACROSS THE LED WHILE ADJUSTING R1. AT SOME POINT THE TONE WILL CHANGE OR STOP WHEN LIGHT STRIKES THE LED AND ALTERS ITS CAPACITANCE. A LASER POINTER WILL CHANGE THE TONE FROM ACROSS A ROOM. (CAUTION: DO NOT AIM A LASER POINTER AT ANOTHER PERSON OR A SHINY SURFACE.)

BUILD AN OP AMP TONE MIXER

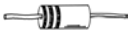
THE 324 INCLUDES FOUR OP AMPS IN A SINGLE PACKAGE. HERE YOU WILL USE TWO OP AMPS TO MAKE A PAIR OF OSCILLATORS AND A THIRD OP AMP TO MIX THEIR SOUNDS.

PARTS YOU WILL NEED





R4-1M (BRN-BLK-GRN)
R5, R6, R8-100K (BRN-BLK-YEL)

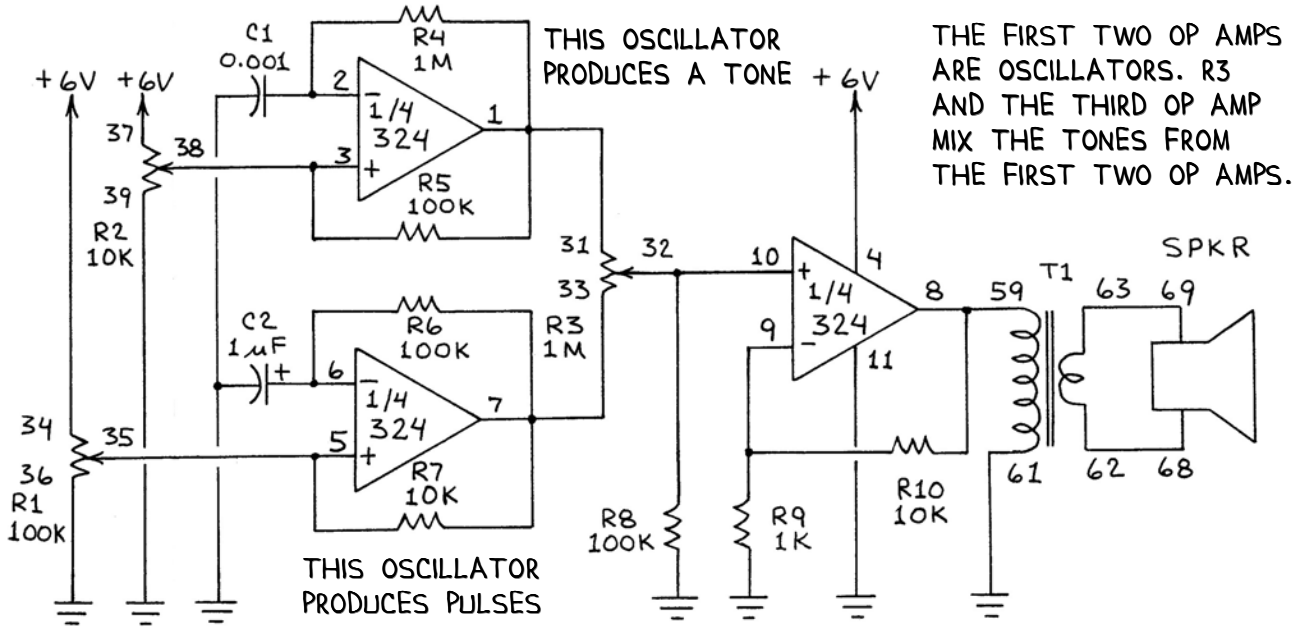


R7, R10-10K (BRN-BLK-ORG)
R9-1K (BRN-BLK-RED)

C1-0.001 UF (102)

C2-1 UF

CIRCUIT DIAGRAM



1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 324 IC OVER SLOT 3 (PIN 1 AT H15).
3. ☐ INSERT R4 ACROSS H11 AND I11.
4. ☐ INSERT R5 ACROSS H13 AND J13.
5. ☐ INSERT R6 ACROSS M11 AND N11.
6. ☐ INSERT R7 ACROSS L13 AND N13.
7. ☐ INSERT C1 ACROSS I14 AND K17.
8. ☐ INSERT C2 ACROSS M14 (+) AND K18 (-).
9. ☐ INSERT R8 ACROSS L18 AND GROUND.
10. ☐ INSERT R9 ACROSS M19 AND GROUND.
11. ☐ INSERT R10 ACROSS M20 AND N20.
12. ☐ CONNECT K20 TO GROUND (WHT WIRE).
13. ☐ CONNECT K11 TO V4 (+6V) (WHT WIRE).
14. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
15. ☐ CONNECT SPRING 38 TO J11 (BLU WIRE).
16. ☐ CONNECT SPRING 37 TO V4 (+6V) (BLU WIRE).
17. ☐ CONNECT SPRING 36 TO GROUND (RED WIRE).
18. ☐ CONNECT SPRING 35 TO L11 (RED WIRE).
19. ☐ CONNECT SPRING 34 TO V4 (+6V) (BLU WIRE).
20. ☐ CONNECT SPRING 33 TO N12 (BLU WIRE).
21. ☐ CONNECT SPRING 32 TO L17 (BLU WIRE).
22. ☐ CONNECT SPRING 31 TO H14 (BLU WIRE).
23. ☐ CONNECT SPRINGS 62 AND 68 (RED WIRE).
24. ☐ CONNECT SPRINGS 63 AND 69 (RED WIRE).
25. ☐ CONNECT SPRING 61 TO GROUND (RED WIRE).
26. ☐ CONNECT SPRING 59 TO N18 (RED WIRE).

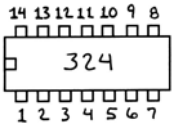
2. TEST THE CIRCUIT

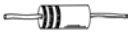
THE PARTS ARE PRETTY CROWDED, SO BE SURE NONE OF THEIR LEADS TOUCH. MAKE SURE THE POWER SUPPLY LEADS ARE PROPERLY CONNECTED. THEN PUSH THE POWER SWITCH UP. YOU WILL HEAR A CONTINUOUS OR PULSATING TONE. ADJUST THE 100K AND 10K CONSOLE POTS (R1 AND R2) TO CONTROL THE SIGNALS FROM THE TWO OSCILLATORS. ADJUST THE 1M CONSOLE POT (R3) TO MIX THE TONE AND PULSES. YOU CAN PRODUCE SOME VERY NEAT SOUND EFFECTS.

BUILD AN OP AMP BARGRAPH LIGHT METER

YOU WILL BUILD A LIGHT METER THAT USES ALL FOUR OP AMPS IN A 324 TO FORM A LADDER COMPARATOR. IT'S A GOOD EXAMPLE OF A PRACTICAL COMPARATOR APPLICATION.

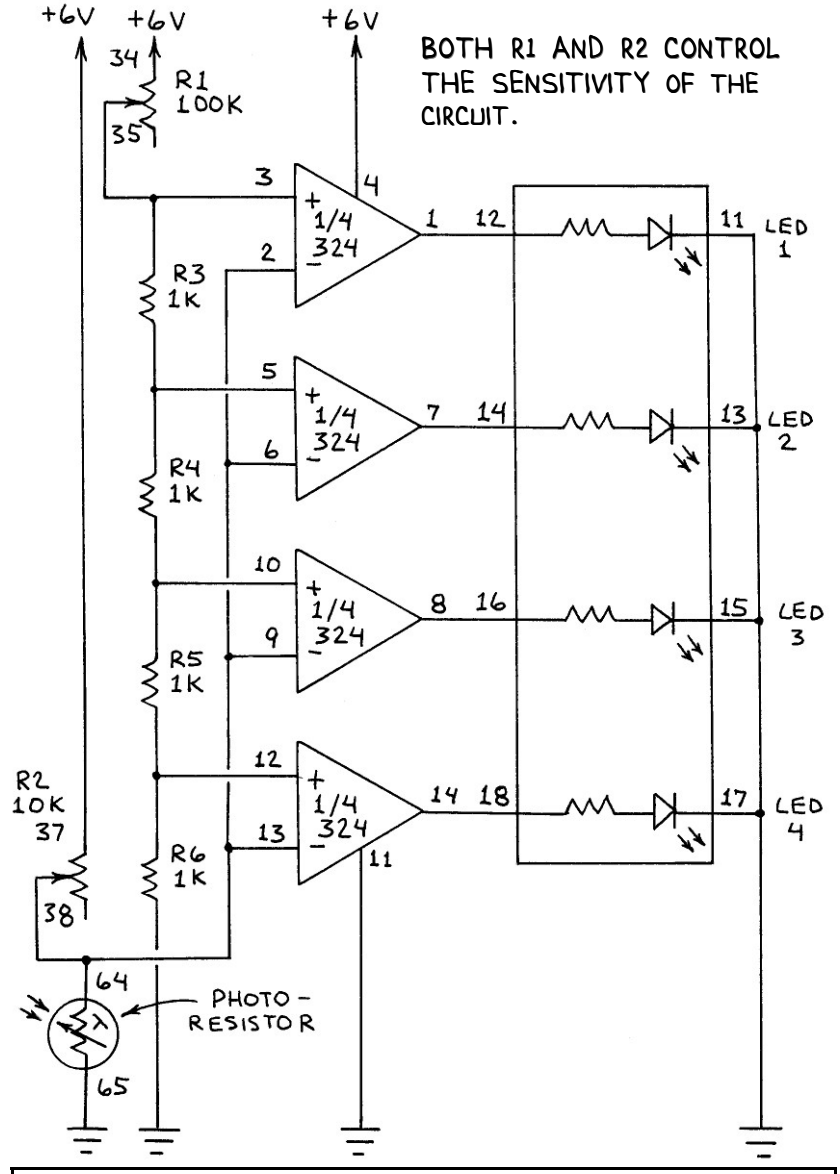
PARTS YOU WILL NEED





R3, R4, R5, R6-1K (BRN-BLK-RED)

CIRCUIT DIAGRAM



2. TEST THE CIRCUIT

CHECK FOR ERRORS. ROTATE THE 100K CONSOLE POT (R1) FULL RIGHT. PUSH THE POWER SWITCH ON. SHINE A FLASHLIGHT ON THE PHOTORESISTOR AND ROTATE THE 10K CONSOLE POT (R2) UNTIL ALL FOUR LEDS GLOW. AS YOU SLOWLY MOVE THE LIGHT AWAY FROM THE PHOTO-RESISTOR, THE LEDS WILL SWITCH OFF IN SEQUENCE.

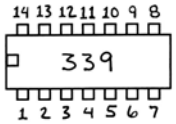
1. BUILD THE CIRCUIT

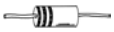
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 324 IC OVER SLOT 3 (PIN 1 AT H15).
3. ☐ CONNECT K20 TO GROUND (WHT WIRE).
4. ☐ CONNECT K11 TO V4 (+6V) (WHT WIRE).
5. ☐ CONNECT I11 TO M11 (WHT WIRE).
6. ☐ CONNECT M14 TO M17 (WHT WIRE).
7. ☐ CONNECT M20 TO I20 (WHT WIRE).
8. ☐ INSERT R3 ACROSS J11 AND L11.
9. ☐ INSERT R4 ACROSS L14 AND L17.
10. ☐ INSERT R5 ACROSS L20 AND J20.
11. ☐ INSERT R6 ACROSS J19 AND GROUND.
12. ☐ CONNECT SPRINGS 38 AND 64 (YEL WIRE).
13. ☐ CONNECT SPRING 65 TO GROUND (BLU WIRE).
14. ☐ CONNECT SPRING 38 TO I17 (BLU WIRE).
15. ☐ CONNECT SPRING 37 TO V4 (+6V) (BLU WIRE).
16. ☐ CONNECT SPRING 35 TO J12 (RED WIRE).
17. ☐ CONNECT SPRING 34 TO V4 (+6V) (BLU WIRE).
18. ☐ CONNECT SPRINGS 11 AND 13 (WHT WIRE).
19. ☐ CONNECT SPRINGS 13 AND 15 (WHT WIRE).
20. ☐ CONNECT SPRINGS 15 AND 17 (WHT WIRE).
21. ☐ CONNECT SPRING 17 TO GROUND (BLU WIRE).
22. ☐ CONNECT SPRING 12 TO H11 (RED WIRE).
23. ☐ CONNECT SPRING 14 TO N11 (RED WIRE).
24. ☐ CONNECT SPRING 16 TO N20 (RED WIRE).
25. ☐ CONNECT SPRING 18 TO H20 (RED WIRE).

BUILD A BUZZER TRIGGERED BY LIGHT OR DARKNESS

YOU WILL USE ONE OF THE FOUR COMPARATORS IN A 339 QUAD COMPARATOR TO TRIGGER A BUZZER WHEN THE PHOTORESISTOR IS ILLUMINATED OR DARK. THE DPDT SWITCH WILL ALLOW YOU TO SELECT BETWEEN A LIGHT-ACTIVATED BUZZER AND A DARK-ACTIVATED BUZZER.

PARTS YOU WILL NEED

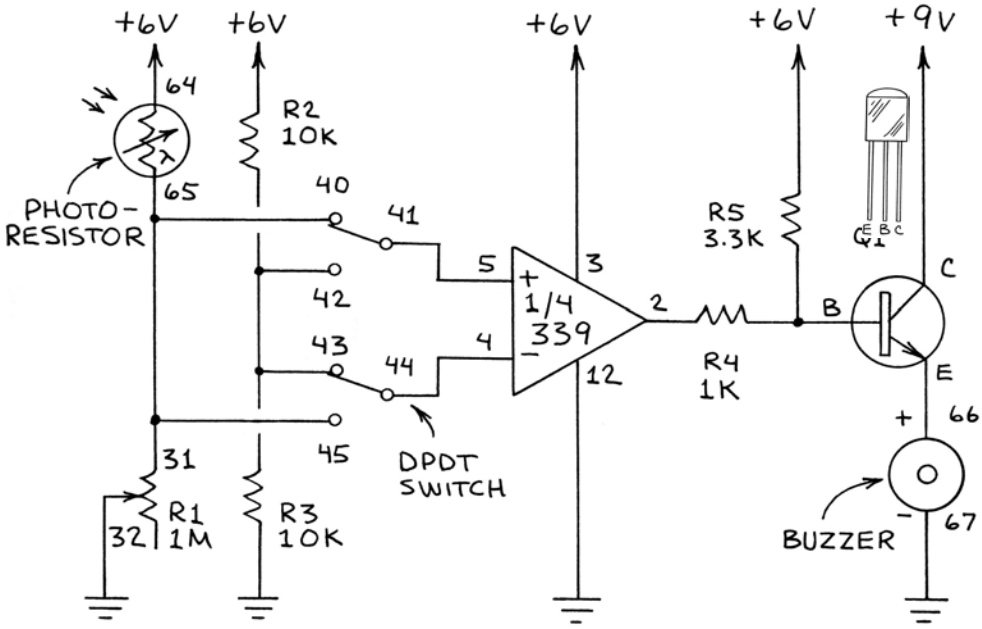




R2, R3-10K (BRN-BLK-ORG)
R4-1K OHMS (BRN-BLK-RED)
R5-3.3K (ORG-ORG-RED)

Q1-NPN TRANSISTOR (9014)

CIRCUIT DIAGRAM



THE PHOTORESISTOR AND R1 FORM A LIGHT-SENSITIVE VOLTAGE DIVIDER. R2 AND R3 FORM A VOLTAGE DIVIDER THAT PROVIDES A REFERENCE VOLTAGE TO THE COMPARATOR.

DARK-ACTIVATED BUZZER: ROTATE R1 TO LEFT UNTIL BUZZER JUST STOPS. PUSH DPDT SWITCH DOWN.

LIGHT-ACTIVATED BUZZER: ROTATE R1 TO RIGHT UNTIL BUZZER JUST STOPS. PUSH DPDT SWITCH UP.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 339 IC OVER SLOT 5 (PIN 1 AT H25).
3. ☐ INSERT Q1 AT S28 (E), Q28 (B) AND O28 (C).
4. ☐ INSERT R2 ACROSS J21 AND Q21.
5. ☐ INSERT R3 ACROSS Q25 AND GROUND.
6. ☐ INSERT R4 ACROSS I22 AND Q26.
7. ☐ INSERT R5 ACROSS J24 AND Q27.
8. ☐ CONNECT J30 TO GROUND (WHT WIRE).
9. ☐ CONNECT J22 TO V4 (+6V) (WHT WIRE).
10. ☐ CONNECT O30 TO V6 (+9V) (WHT WIRE).
11. ☐ CONNECT SPRINGS 40 AND 45 (WHT WIRE).
12. ☐ CONNECT SPRINGS 42 AND 43 (WHT WIRE).
13. ☐ CONNECT SPRINGS 31 AND 40 (BLU WIRE).
14. ☐ CONNECT SPRING 31 AND 65 (YEL WIRE).
15. ☐ CONNECT SPRING 32 TO GROUND (RED WIRE).
16. ☐ CONNECT SPRING 41 TO L21 (BLU WIRE).
17. ☐ CONNECT SPRING 44 AND K21 (BLU WIRE).
18. ☐ CONNECT SPRING 43 AND Q23 (RED WIRE).
19. ☐ CONNECT SPRING 64 AND V4 (+6V) (BLU WIRE).
20. ☐ CONNECT SPRING 66 AND S30 (BLU WIRE).
21. ☐ CONNECT SPRING 67 AND GROUND (BLU WIRE).

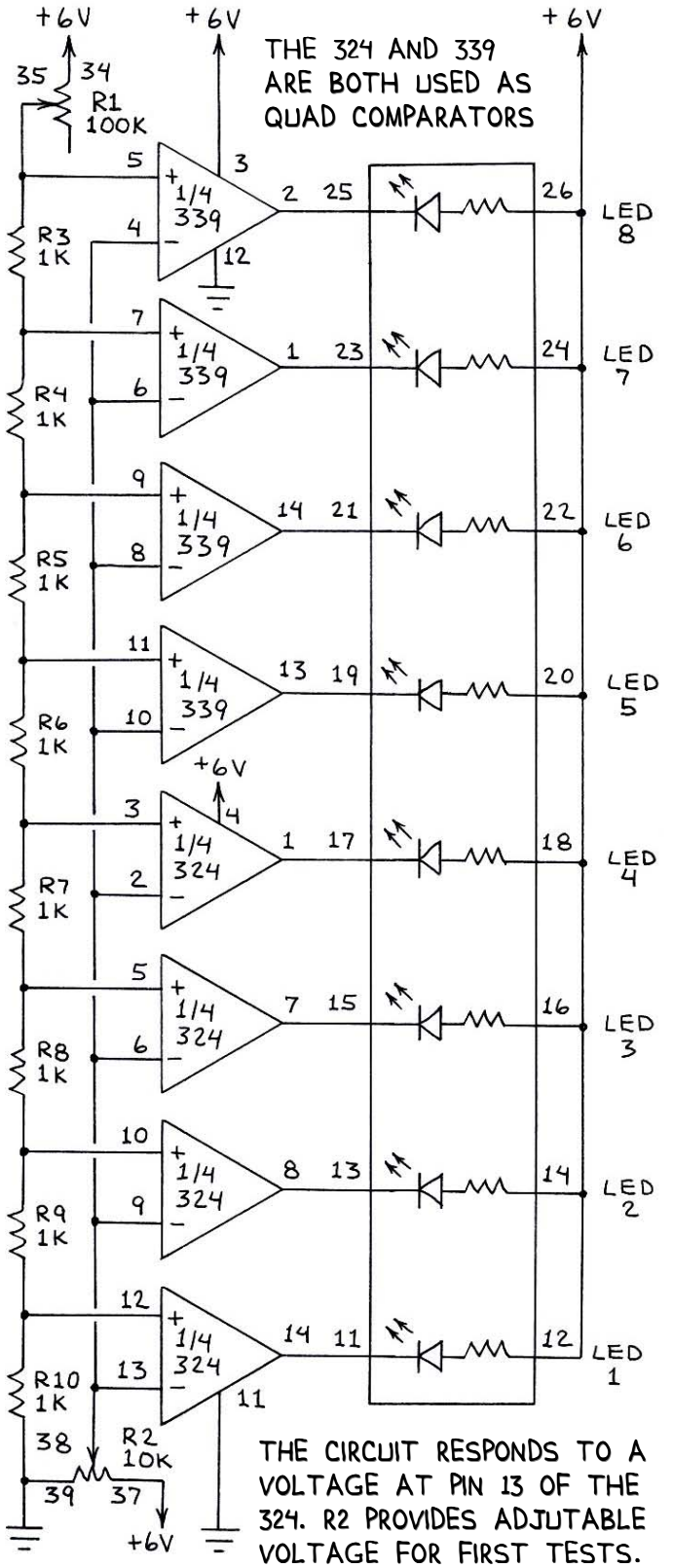
2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. PUSH THE DPDT SWITCH UP AND ROTATE THE 1M CONSOLE POT (R1) TO THE RIGHT. PUSH THE POWER SWITCH UP. SLOWLY ROTATE R1 TO THE LEFT UNTIL THE BUZZER JUST SOUNDS. PLACE YOUR INDEX FINGER OVER THE PHOTORESISTOR, AND THE BUZZER WILL SWITCH OFF. THIS IS THE LIGHT-ACTIVATED MODE. NOW PUSH THE DPDT SWITCH DOWN AND SHADE THE PHOTORESISTOR. THE BUZZER WILL SWITCH ON. THIS IS THE DARK-ACTIVATED MODE. EXPERIMENT WITH R1'S SETTING FOR BEST RESULTS.

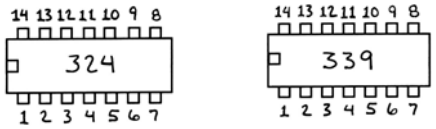
BUILD AN 8-LEVEL LED BARGRAPH READOUT

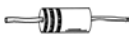
YOU WILL BUILD AN 8-STAGE LADDER COMPARATOR THAT CONVERTS THE CONSOLE LEDS INTO AN 8-LEVEL BARGRAPH. THIS IS A MUST-BUILD CIRCUIT WITH MANY NEAT USES.

CIRCUIT DIAGRAM



PARTS YOU WILL NEED





R3, R4, R5, R6, R7, R8, R9, R10-1K (BRN-BLK-RED)

1. BUILD THE COMPARATOR CIRCUITS FIRST

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 324 IC OVER SLOT 3 (PIN 1 AT H15).
3. ☐ INSERT 339 IC OVER SLOT 5 (PIN 1 AT H25).
4. ☐ CONNECT K20 TO GROUND (WHT WIRE).
5. ☐ CONNECT K11 TO V4 (+6V) (WHT WIRE).
6. ☐ CONNECT J30 TO GROUND (WHT WIRE).
7. ☐ CONNECT J21 TO V4 (+6V) (WHT WIRE).
8. ☐ INSERT R7 ACROSS J11 AND L11.
9. ☐ INSERT R8 ACROSS L14 AND L17.
10. ☐ INSERT R9 ACROSS L20 AND J20.
11. ☐ INSERT R10 ACROSS J18 AND GROUND.
12. ☐ INSERT R3 ACROSS L21 AND N21.
13. ☐ INSERT R4 ACROSS N24 AND M27.
14. ☐ INSERT R5 ACROSS M30 AND K30.
15. ☐ INSERT R6 ACROSS K27 AND D27.
16. ☐ CONNECT D26 TO J14 (RED WIRE).
17. ☐ CONNECT I11 TO M11 (WHT WIRE).
18. ☐ CONNECT M14 TO M17 (WHT WIRE).
19. ☐ CONNECT M20 TO I20 (WHT WIRE).
20. ☐ CONNECT I19 TO K22 (WHT WIRE).
21. ☐ CONNECT K21 TO M21 (WHT WIRE).
22. ☐ CONNECT M24 TO N27 (WHT WIRE).
23. ☐ CONNECT N30 TO L30 (WHT WIRE).

2. CONNECT THE CONSOLE POTS NEXT

1. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
2. ☐ CONNECT SPRING 38 TO I14 (BLU WIRE).
3. ☐ CONNECT SPRING 37 TO V4 (+6V) (BLU WIRE).
4. ☐ CONNECT SPRING 35 TO L24 (BLU WIRE).
5. ☐ CONNECT SPRING 34 TO V4 (+6V) (BLU WIRE).

3. CONNECT THE CONSOLE LEDS

NEARLY ALL THE PROJECTS IN YOUR ELECTRONICS LEARNING LAB THAT USE THE CONSOLE LEDS CONNECT THE ANODE(S) (SPRINGS 12, 14, 16, ETC.) TO THE CIRCUIT AND THE CATHODE(S) (SPRINGS 11, 13, 15, ETC.) TO GROUND. THIS FORMS A COMMON CATHODE DISPLAY. (THE SEVEN-SEGMENT READOUT ON YOUR CONSOLE IS ALSO A COMMON CATHODE DISPLAY.) IN THIS PROJECT, THE CATHODES ARE CONNECTED TO THE CIRCUIT AND THE ANODES ARE CONNECTED DIRECTLY TO THE POSITIVE VOLTAGE. THIS ROW OF LEDS IS THEREFORE A COMMON ANODE DISPLAY.

1. ☐ CONNECT SPRINGS 12 AND 14 (WHT WIRE).
2. ☐ CONNECT SPRINGS 14 AND 16 (WHT WIRE).
3. ☐ CONNECT SPRINGS 16 AND 18 (WHT WIRE).
4. ☐ CONNECT SPRINGS 18 AND 20 (WHT WIRE).
5. ☐ CONNECT SPRINGS 20 AND 22 (WHT WIRE).
6. ☐ CONNECT SPRINGS 22 AND 24 (WHT WIRE).
7. ☐ CONNECT SPRINGS 24 AND 26 (WHT WIRE).
8. ☐ CONNECT SPRING 12 TO V4 (+6V) (WHT WIRE).
9. ☐ CONNECT SPRING 11 TO H17 (BLU WIRE).
10. ☐ CONNECT SPRING 13 TO N18 (BLU WIRE).
11. ☐ CONNECT SPRING 15 TO N14 (BLU WIRE).
12. ☐ CONNECT SPRING 17 TO H14 (BLU WIRE).
13. ☐ CONNECT SPRING 19 TO I30 (BLU WIRE).
14. ☐ CONNECT SPRING 21 TO H30 (BLU WIRE).
15. ☐ CONNECT SPRING 23 TO H24 (YEL WIRE).
16. ☐ CONNECT SPRING 25 TO I24 (YEL WIRE).

THIS IS A CROWDED CIRCUIT WITH 16 EXPOSED COMPONENT LEADS (THE RESISTORS) AND SOME 30 CONNECTION WIRES. SO CHECK YOUR WIRING CAREFULLY. MAKE SURE THE POWER SUPPLY PINS ON BOTH ICS ARE PROPERLY CONNECTED. THE 100K CONSOLE POT (R1) CONTROLS THE CIRCUIT'S SENSITIVITY. ROTATE R1 ALL THE WAY TO THE RIGHT FOR THE INITIAL TEST. THE 10K CONSOLE POT (R2) IS CONNECTED AS A VOLTAGE DIVIDER THAT PROVIDES AN ADJUSTABLE VOLTAGE TO THE CIRCUIT'S INPUT. ROTATE R2 ALL THE WAY TO THE LEFT FOR THE INITIAL TEST. THEN PUSH THE POWER SWITCH UP.

ALL THE LEDS SHOULD BE OFF. SLOWLY ROTATE R2 TO THE RIGHT TO APPLY SOME VOLTAGE TO THE CIRCUIT'S INPUT. AT SOME POINT LED 1 WILL GLOW. CONTINUE ROTATING R2 TO INCREASE THE VOLTAGE, AND LED 2 WILL GLOW. CONTINUE ROTATING R2, AND EVENTUALLY ALL EIGHT LEDS WILL BE GLOWING. ROTATE R2 BACK TO THE LEFT AND THE LEDS WILL SWITCH OFF ONE BY ONE.

THIS CIRCUIT LOOKS COMPLICATED, BUT IT'S ACTUALLY VERY SIMPLE. IF SOME OF THE LEDS FAIL TO GLOW, CHECK THE RESISTOR AND WHITE CONNECTION WIRE CONNECTED TO THE LED'S COMPARATOR. WHEN NO LEDS GLOW, THE PROBLEM COULD BE A MISSING OR INCORRECT CONNECTION TO THE POWER SUPPLY (+6V AND GROUND) OR ONE OF THE TWO POTS.

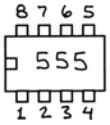
5. GOING FURTHER

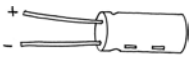
THIS CIRCUIT HAS MANY USES. SUPER-SENSITIVE RESISTANCE METER: REMOVE THE BLUE WIRE AT SPRING 38 AND GRASP THE EXPOSED END WITH YOUR FINGERS. PUSH THE POWER SWITCH ON AND ALL 8 LEDS WILL GLOW. NOW LIGHTLY TOUCH SPRING 39 (GROUND). SOME OF THE LEDS WILL SWITCH OFF. PRESS HARDER, AND ALL THE LEDS WILL SWITCH OFF. (ADJUST R1 IF ANY LEDS STAY ON.) TIMER: CONNECT A 10 UF CAPACITOR ACROSS THE BLUE WIRE (+) AND GROUND (-). DISCHARGE THE CAPACITOR BY BRIEFLY SHORTING ITS LEADS TOGETHER WITH A RED WIRE. THE LEDS WILL GLOW IN SEQUENCE AS THE CAPACITOR IS CHARGED THROUGH THE CHAIN OF RESISTORS. SHORT THE CAPACITOR LEADS AGAIN TO REPEAT THE CYCLE. SUPER-SENSITIVE DARK METER: CONNECT THE BLUE WIRE TO SPRING 64 AND CONNECT SPRING 65 TO GROUND (BLU WIRE). THEN MOVE THE BLUE WIRES AT SPRINGS 34 AND 35 TO SPRINGS 31 AND 32 TO MAKE THE CIRCUIT MORE SENSITIVE. THE CIRCUIT IS NOW A DARK METER. DIM THE LIGHTS, PLACE A FINGER OVER THE PHOTORESISTOR AND ADJUST THE 1M CONSOLE POT FOR BEST RESULTS. YOU CAN ADJUST THE 1M POT SO THAT LIGHT CAUSES ALL THE LEDS TO SWITCH OFF. DARKENING THE PHOTORESISTOR WILL THEN CAUSE THE LEDS TO GLOW IN SEQUENCE. NOW IT'S YOUR TURN TO THINK OF MORE USES FOR THIS AMAZING CIRCUIT.

555 TIMER CIRCUITS: BUILD A KEYBOARD OSCILLATOR

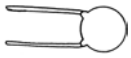
YOU WILL USE A 555 TO BUILD A KEYBOARD OSCILLATOR THAT PRODUCES FOUR SEPARATE TONES. YOU WILL USE A SINGLE POT TO CONTROL THE FREQUENCY OF ALL FOUR TONES.

PARTS YOU WILL NEED

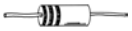




C1–1 UF
C5–10 UF



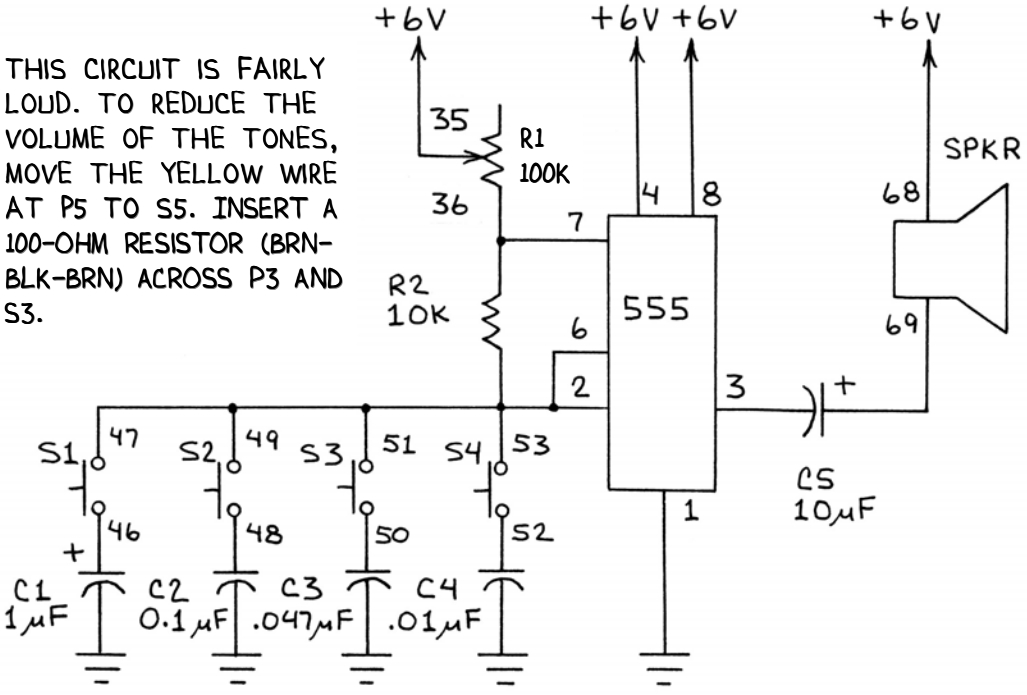
C2–0.1 UF (104)
C3–0.047 UF (473)
C4–0.01 (103)



R2–10K (BRN-BLK-ORG)

CIRCUIT DIAGRAM

THIS CIRCUIT IS FAIRLY LOUD. TO REDUCE THE VOLUME OF THE TONES, MOVE THE YELLOW WIRE AT P5 TO S5. INSERT A 100-OHM RESISTOR (BRN-BLK-BRN) ACROSS P3 AND S3.



2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. PUSH THE POWER SWITCH UP AND PRESS S1. ROTATE THE 100K CONSOLE POT (R1) UNTIL YOU HEAR A BUZZ OR TONE. DO THE SAME FOR S2, S3 AND S4. YOU SHOULD NOW HEAR A SERIES OF TONES WHEN YOU PRESS S1 THROUGH S4 IN SEQUENCE. ADJUST R1 TO OPTIMIZE THE RANGE OF THE TONES. PRESS MORE THAN ONE SWITCH FOR MORE TONES.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 555 ACROSS SLOT 1 (PIN 1 AT J5).
3. ☐ INSERT R2 ACROSS K10 AND L10.
4. ☐ INSERT C1 ACROSS T3 (+) AND GROUND (–).
5. ☐ INSERT C2 ACROSS T8 AND GROUND.
6. ☐ INSERT C3 ACROSS T13 AND GROUND.
7. ☐ INSERT C4 ACROSS T18 AND GROUND.
8. ☐ INSERT C5 ACROSS P1 (+) AND L1 (–).
9. ☐ CONNECT K4 AND L7 (WHT WIRE).
10. ☐ CONNECT M4 AND J7 (WHT WIRE).
11. ☐ CONNECT J1 AND GROUND (WHT WIRE).
12. ☐ CONNECT J10 AND V4 (+6V) (WHT WIRE).
13. ☐ CONNECT SPRING 35 TO J8 (RED WIRE).
14. ☐ CONNECT SPRING 36 TO K8 (RED WIRE).
15. ☐ CONNECT SPRING 68 TO V4 (+6V) (BLU WIRE).
16. ☐ CONNECT SPRING 69 TO P5 (YEL WIRE).
17. ☐ CONNECT SPRING 47 TO K1 (BLU WIRE).
18. ☐ CONNECT SPRING 46 TO T5 (RED WIRE).
19. ☐ CONNECT SPRING 48 TO T10 (RED WIRE).
20. ☐ CONNECT SPRING 50 TO T15 (RED WIRE).
21. ☐ CONNECT SPRING 52 TO T20 (RED WIRE).
22. ☐ CONNECT SPRINGS 47 AND 49 (WHT WIRE).
23. ☐ CONNECT SPRINGS 49 AND 51 (WHT WIRE).
24. ☐ CONNECT SPRINGS 51 AND 53 (WHT WIRE).

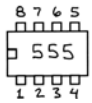
3. GOING FURTHER

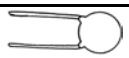
YOU CAN ADD SOME SPICE TO THIS CIRCUIT BY MAKING IT SENSITIVE TO LIGHT. USE BLUE WIRES TO CONNECT SPRINGS 35 AND 64 AND SPRINGS 36 AND 65.

BUILD A VOLTAGE-CONTROLLED OSCILLATOR (VCO)

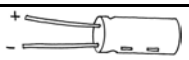
YOU WILL USE A 555 TO BUILD AN OSCILLATOR WHOSE FREQUENCY IS DETERMINED BY VOLTAGE.

PARTS YOU WILL NEED

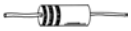




C1-0.1 UF (104)

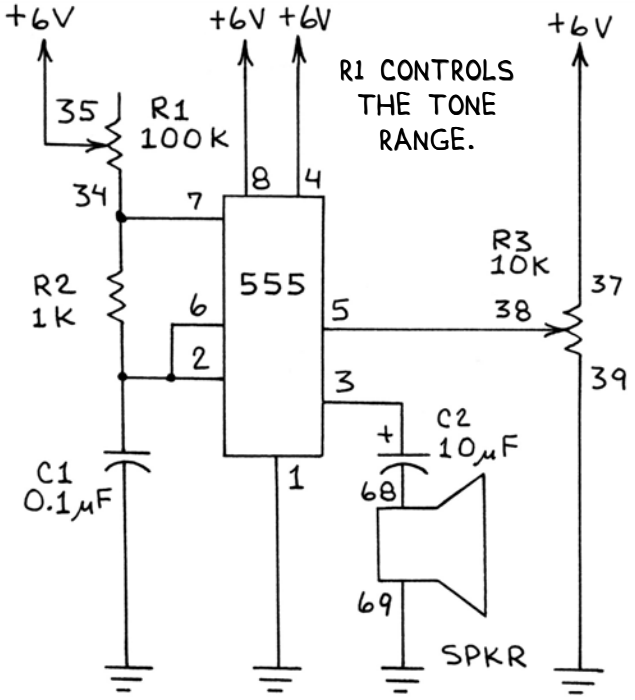


C2-10 UF



R2-1K (BRN-BLK-RED)

CIRCUIT DIAGRAM



R3 IS USED AS A VOLTAGE DIVIDER.

1. BUILD THE CIRCUIT

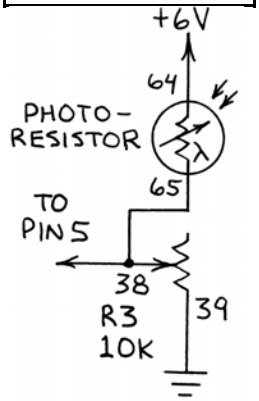
1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 555 ACROSS SLOT 1 (PIN 1 AT J5).
3. ☐ INSERT R2 ACROSS K10 AND L10.
4. ☐ INSERT C1 ACROSS J2 AND K2.
5. ☐ INSERT C2 ACROSS L1 (+) AND P1 (-).
6. ☐ CONNECT K4 AND L7 (WHT WIRE).
7. ☐ CONNECT M4 AND J7 (WHT WIRE).
8. ☐ CONNECT J1 AND GROUND (WHT WIRE).
9. ☐ CONNECT J10 AND V4 (+6V) (WHT WIRE).
10. ☐ CONNECT SPRING 34 TO K7 (RED WIRE).
11. ☐ CONNECT SPRING 35 TO V4 (+6V) (BLU WIRE).
12. ☐ CONNECT SPRING 38 TO M9 (BLU WIRE).
13. ☐ CONNECT SPRING 39 TO GROUND (RED WIRE).
14. ☐ CONNECT SPRING 37 TO V4 (+6V) (BLU WIRE).
15. ☐ CONNECT SPRING 68 TO P5 (YEL WIRE).
16. ☐ CONNECT SPRING 69 TO GROUND (BLU WIRE).

2. TEST THE CIRCUIT

PUSH THE POWER SWITCH UP. ROTATE THE 10K CONSOLE POT (R3) TO CHANGE THE VOLTAGE AT PIN 5 AND THEREBY THE FREQUENCY.

BUILD A LIGHT-CONTROLLED DOWN TONE

CIRCUIT DIAGRAM



2. TEST THE CIRCUIT

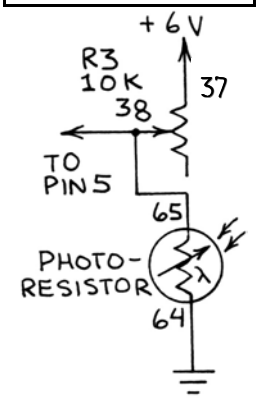
SET THE 10K CONSOLE POT (R3) TO ITS MID-POINT. PUSH THE POWER SWITCH ON. SHINE LIGHT ON THE PHOTORESISTOR. THE TONE FREQUENCY WILL FALL. ADJUST THE 100K CONSOLE POT (R1) TO CHANGE THE OVERALL TONE RANGE.

1. MODIFY THE VCO CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE BLUE WIRE BETWEEN SPRING 37 AND V4 (+6V).
3. ☐ CONNECT SPRINGS 65 AND 38 (YEL WIRE).
4. ☐ CONNECT SPRING 64 TO V4 (+6V) (BLU WIRE).

BUILD A LIGHT-CONTROLLED UP TONE

CIRCUIT DIAGRAM



2. TEST THE CIRCUIT

SET THE 10K CONSOLE POT (R3) TO ITS MID-POINT. PUSH THE POWER SWITCH ON. SHINE LIGHT ON THE PHOTORESISTOR. THE TONE FREQUENCY WILL RISE. TOO LOUD? INSERT 100-OHM RESISTOR BETWEEN SPEAKER SPRING 69 AND C2.

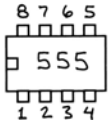
1. MODIFY THE VCO CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ REMOVE RED WIRE BETWEEN SPRING 39 AND GROUND.
3. ☐ CONNECT SPRINGS 65 AND 38 (YEL WIRE).
4. ☐ CONNECT SPRING 64 TO GROUND (BLU WIRE).

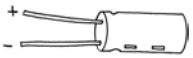
BUILD A LIGHT-DARK DETECTOR

YOU WILL BUILD A CIRCUIT THAT EMITS A TONE WHEN THE PHOTORESISTOR IS EITHER DARK OR ILLUMINATED. YOU WILL USE THE DPDT SWITCH TO SELECT BETWEEN THESE MODES.

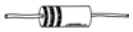
PARTS YOU WILL NEED



C1-0.1 UF (104)

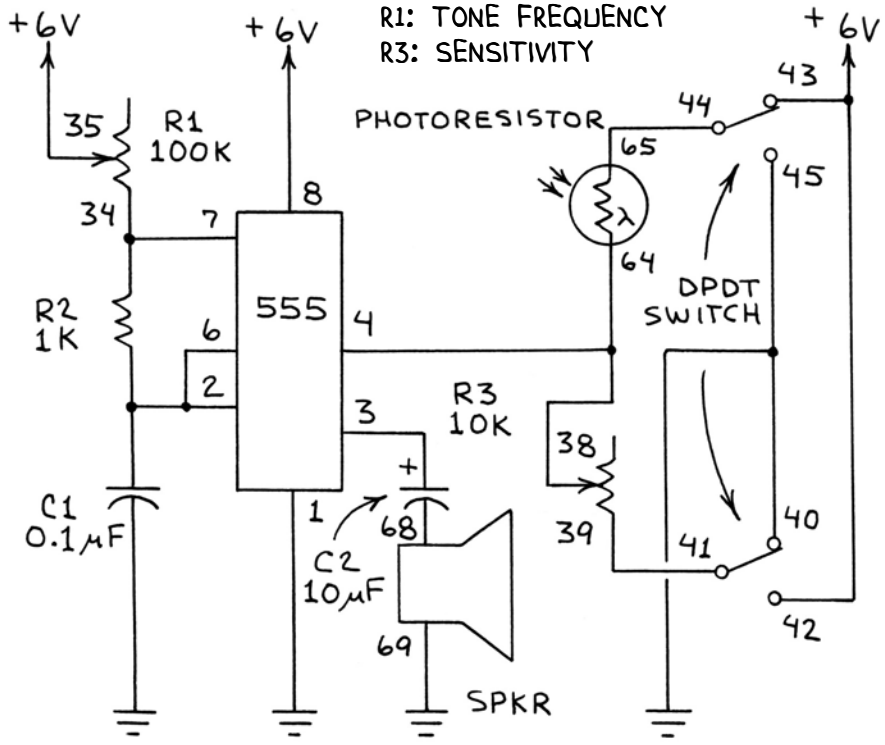


C2-10 UF



R2-1K (BRN-BLK-RED)

CIRCUIT DIAGRAM



2. TEST THE CIRCUIT

CHECK FOR ERRORS. ROTATE THE 100K CONSOLE POT (R1) TO ITS MIDPOINT. ROTATE THE 10K CONSOLE POT (R3) TO THE FAR LEFT. PUSH THE DPDT SWITCH DOWN AND THE POWER SWITCH ON. A TONE WILL SOUND. SHINE A BRIGHT FLASHLIGHT ON THE PHOTORESISTOR AND ROTATE R3 TO THE RIGHT UNTIL THE TONE STOPS. REMOVE THE FLASHLIGHT, AND THE TONE WILL SOUND AGAIN. PUSH THE DPDT SWITCH UP AND SHINE THE FLASHLIGHT ON THE PHOTORESISTOR. THE TONE WILL SOUND. REMOVE THE FLASHLIGHT, AND THE TONE WILL STOP. ADJUST R3 FOR BEST RESULTS. ADJUST R1 TO CHANGE THE FREQUENCY.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 555 ACROSS SLOT 1 (PIN 1 AT J5).
3. ☐ INSERT R1 ACROSS K10 AND L10.
4. ☐ INSERT C1 ACROSS J2 AND K2.
5. ☐ INSERT C2 ACROSS L1 (+) AND P1 (-).
6. ☐ CONNECT K4 AND L7 (WHT WIRE).
7. ☐ CONNECT J1 AND GROUND (WHT WIRE).
8. ☐ CONNECT J10 AND V4 (+6V) (WHT WIRE).
9. ☐ CONNECT SPRING 34 TO K7 (RED WIRE).
10. ☐ CONNECT SPRING 35 TO V4 (+6V) (BLU WIRE).
11. ☐ CONNECT SPRING 38 TO M2 (RED WIRE).
12. ☐ CONNECT SPRING 40 TO GROUND (RED WIRE).
13. ☐ CONNECT SPRING 43 TO V4 (+6V) (BLU WIRE).
14. ☐ CONNECT SPRINGS 39 AND 41 (WHT WIRE).
15. ☐ CONNECT SPRINGS 40 AND 45 (WHT WIRE).
16. ☐ CONNECT SPRINGS 42 AND 43 (WHT WIRE).
17. ☐ CONNECT SPRINGS 44 AND 65 (BLU WIRE).
18. ☐ CONNECT SPRING 64 TO M4 (YEL WIRE).
19. ☐ CONNECT SPRING 68 TO P5 (BLU WIRE).
20. ☐ CONNECT SPRING 69 TO GROUND (BLU WIRE).

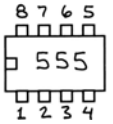
3. GOING FURTHER

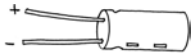
YOU CAN EXPERIMENT WITH THE ADJUSTMENT OF R3 TO CHANGE THE SENSITIVITY OF THIS CIRCUIT. THE VOLUME OF THE TONE IS FAIRLY LOUD. REDUCE IT BY INSERTING A 100-OHM RESISTOR BETWEEN THE SPEAKER AND C2. MOVE THE BLUE WIRE AT P5 TO T5. INSERT THE 100-OHM RESISTOR ACROSS P3 AND T3.

BUILD A PROGRAMMABLE TIMER

YOU WILL USE A 555 TO BUILD A TIMER THAT WILL ACTIVATE THE BUZZER AND AN LED FOR 0 TO 10 SECONDS, OR 0 TO 100 SECONDS. YOU WILL USE THE DPDT SWITCH TO SELECT THE DELAY RANGE AND A CONSOLE POT TO FINE-TUNE THE DESIRED DELAY WITHIN THE RANGE.

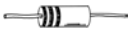
PARTS YOU WILL NEED





C1-100 UF
C2-10 UF

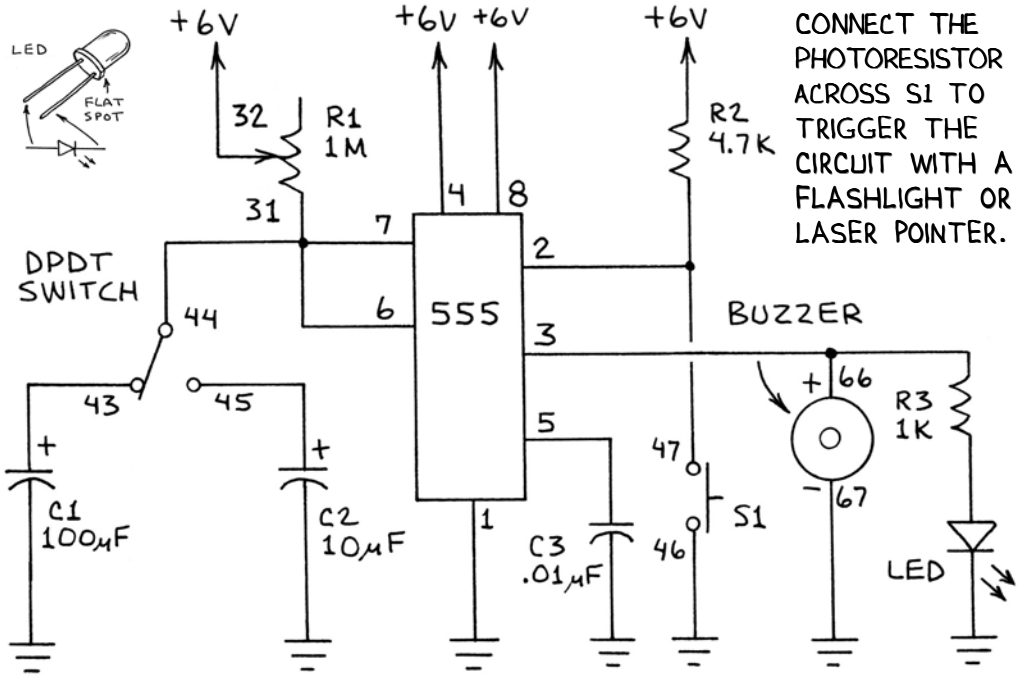
C3-0.01 UF (103)



R2-4.7K (YEL-VIO-RED)
R3-1K (BRN-BLK-RED)

LED-RED

CIRCUIT DIAGRAM



2. TEST THE CIRCUIT

CONNECT THE PHOTORESISTOR ACROSS S1 TO TRIGGER THE CIRCUIT WITH A FLASHLIGHT OR LASER POINTER.

FIRST CHECK YOUR WIRING FOR ERRORS. PUSH THE DPDT SWITCH DOWN (10 SECOND RANGE) AND ROTATE THE 1M CONSOLE POT ALL THE WAY TO THE LEFT. PRESS S1. THE BUZZER WILL SOUND AND THE LED WILL GLOW FOR ABOUT 10 SECONDS AND THEN SWITCH OFF. CHANGE THE SETTING OF R1 AND TRY AGAIN. THEN PUSH THE DPDT SWITCH UP AND TRY THE 0 TO 100 SECOND RANGE.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 555 ACROSS SLOT 1 (PIN 1 AT J5).
3. ☐ INSERT C1 ACROSS T3 (+) AND GROUND (-).
4. ☐ INSERT C2 ACROSS T8 (+) AND GROUND (-).
5. ☐ INSERT C3 ACROSS J4 AND M7.
6. ☐ INSERT R2 ACROSS J9 AND P9.
7. ☐ INSERT R3 ACROSS L1 AND R1.
8. ☐ INSERT LED ACROSS R5 (ANODE) AND GROUND (CATHODE).
9. ☐ CONNECT M4 AND J7 (WHT WIRE).
10. ☐ CONNECT K10 AND L10 (WHT WIRE).
11. ☐ CONNECT J1 AND GROUND (WHT WIRE).
12. ☐ CONNECT J10 AND V4 (+6V) (WHT WIRE).
13. ☐ CONNECT SPRING 31 TO K8 (RED WIRE).
14. ☐ CONNECT SPRING 32 TO V4 (+6V) (BLU WIRE).
15. ☐ CONNECT SPRING 43 TO T1 (RED WIRE).
16. ☐ CONNECT SPRING 44 TO L7 (RED WIRE).
17. ☐ CONNECT SPRING 45 TO T10 (RED WIRE).
18. ☐ CONNECT SPRING 46 TO GROUND (WHT WIRE).
19. ☐ CONNECT SPRING 47 TO P10 (RED WIRE).
20. ☐ CONNECT SPRING 47 TO K1 (BLU WIRE).
21. ☐ CONNECT SPRING 66 TO L3 (YEL WIRE).
22. ☐ CONNECT SPRING 67 TO GROUND (BLU WIRE).

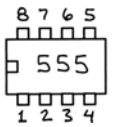
3. GOING FURTHER

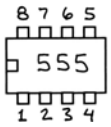
FOR VERY BRIEF DELAYS OF UP TO ABOUT 1 SECOND, REPLACE C1 WITH A 1 UF CAPACITOR. REPLACE C1 WITH A 470 UF CAPACITOR FOR MUCH LONGER DELAYS.

BUILD A MISSING PULSE DETECTOR

YOU WILL BUILD A 555 CIRCUIT THAT SENDS A STREAM OF PULSES TO A SECOND 555 CIRCUIT CONNECTED AS A MONOSTABLE MULTIVIBRATOR OR ONE-SHOT. WHEN THE PULSES STOP OR ARRIVE TOO SLOW TO RESET THE ONE-SHOT, AN LED GLOWS.

PARTS YOU WILL NEED





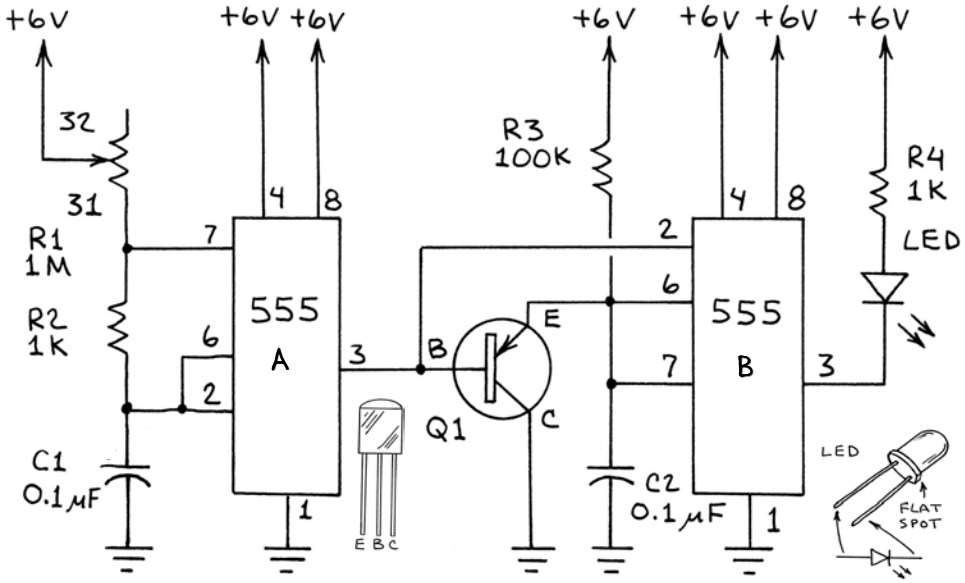
Q1-PNP (9015)

C1, C2-0.1 (104)

R2, R4-1K (BRN-BLK-RED)
R3-100K (BRN-BLK-YEL)

LED-RED

CIRCUIT DIAGRAM



THIS CIRCUIT DEMONSTRATES AN INTRUSION DETECTOR. WHEN PULSES FROM 555-A ARRIVE AT 555-B AT A SUFFICIENTLY FAST RATE, THE LED DOES NOT GLOW. WHEN THE CONNECTION BETWEEN THE ICS IS BROKEN, THE LED GLOWS. TO HEAR THE PULSES, CONNECT SPRING 68 TO GROUND. (BLU WIRE). INSERT A 100-OHM RESISTOR (BRN-BLK-BRN) ACROSS L1 AND T1. CONNECT SPRING 69 TO T5 (YEL WIRE).

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 555 (A) ACROSS SLOT 1 (PIN 1 AT J5).
3. ☐ INSERT 555 (B) ACROSS SLOT 3 (PIN 1 AT J15).
4. ☐ INSERT Q1 AT F13 (E), H13 (B) AND J13 (C).
5. ☐ INSERT LED ACROSS P11 (ANODE) AND L11 (CATHODE).
6. ☐ INSERT C1 ACROSS J2 AND K2.
7. ☐ INSERT C2 ACROSS J14 AND L17.
8. ☐ INSERT R2 ACROSS K9 AND L9.
9. ☐ INSERT R3 ACROSS J19 AND K19.
10. ☐ INSERT R4 ACROSS P14 AND M14.
11. ☐ CONNECT K4 AND L7 (WHT WIRE).
12. ☐ CONNECT M4 AND J7 (WHT WIRE).
13. ☐ CONNECT J1 AND GROUND (WHT WIRE).
14. ☐ CONNECT J10 AND V4 (+6V) (RED WIRE).
15. ☐ CONNECT F15 AND K18 (WHT WIRE).
16. ☐ CONNECT H15 AND K14 (WHT WIRE).
17. ☐ CONNECT K20 AND L20 (WHT WIRE).
18. ☐ CONNECT J17 AND M12 (WHT WIRE).
19. ☐ CONNECT J11 AND GROUND (WHT WIRE).
20. ☐ CONNECT J20 AND V4 (+6V) (RED WIRE).
21. ☐ CONNECT L3 AND K11 (RED WIRE).
22. ☐ CONNECT SPRING 31 TO K7 (RED WIRE).
23. ☐ CONNECT SPRING 32 TO M1 (RED WIRE).

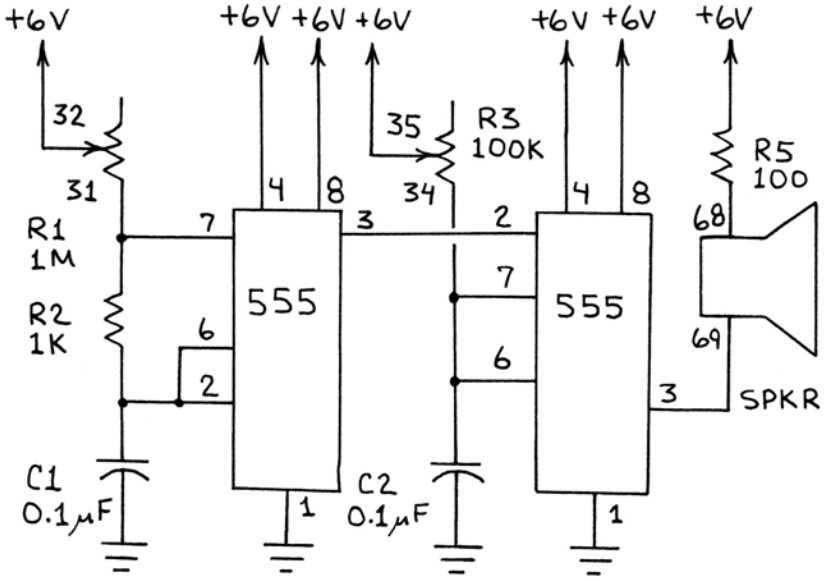
2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. ROTATE THE 1M CONSOLE POT ALL THE WAY TO THE LEFT AND PUSH THE POWER SWITCH UP. THE LED WILL FLICKER OR GLOW TO INDICATE PULSES FROM THE FIRST 555 ARE ARRIVING TOO SLOWLY. SLOWLY ROTATE R1 TO THE RIGHT TO SPEED UP THE PULSES. AT SOME POINT THE LED WILL SWITCH OFF TO INDICATE THAT THE SECOND 555 IS NOT DETECTING MISSING PULSES. TEMPORARILY REMOVE THE RED WIRE AT K11 TO BREAK THE PULSE CONNECTION, AND THE LED WILL GLOW. THIS CIRCUIT CAN BE EASILY MODIFIED FOR MANY NEW APPLICATIONS. THE SOUND EFFECTS CIRCUITS ON PAGE 93 ARE TWO EXAMPLES.

BUILD A SOUND SYNTHESIZER

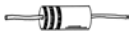
YOU WILL FEED PULSES FROM A 555 PULSE GENERATOR TO A 555 ONE-SHOT TO CREATE SOME FASCINATING SOUNDS. A MUST-BUILD, FUN CIRCUIT.

CIRCUIT DIAGRAM



PARTS YOU WILL NEED

MISSING PULSE CIRCUIT (P. 92) PLUS:



R5-100 OHMS (BRN-BLK-BRN)

2. MODIFY THE MISSING PULSE CIRCUIT

1. ☐ PUSH THE POWER SWITCH OFF.
2. ☐ REMOVE Q1, LED, R3, AND R4.
3. ☐ INSERT R5 ACROSS M11 AND T11.
4. ☐ CONNECT SPRING 68 TO T15 (BLU WIRE).
5. ☐ CONNECT SPRING 69 TO L11 (BLU WIRE).
6. ☐ CONNECT SPRING 35 TO J8 (RED WIRE).
7. ☐ CONNECT SPRING 34 TO L19 (BLU).

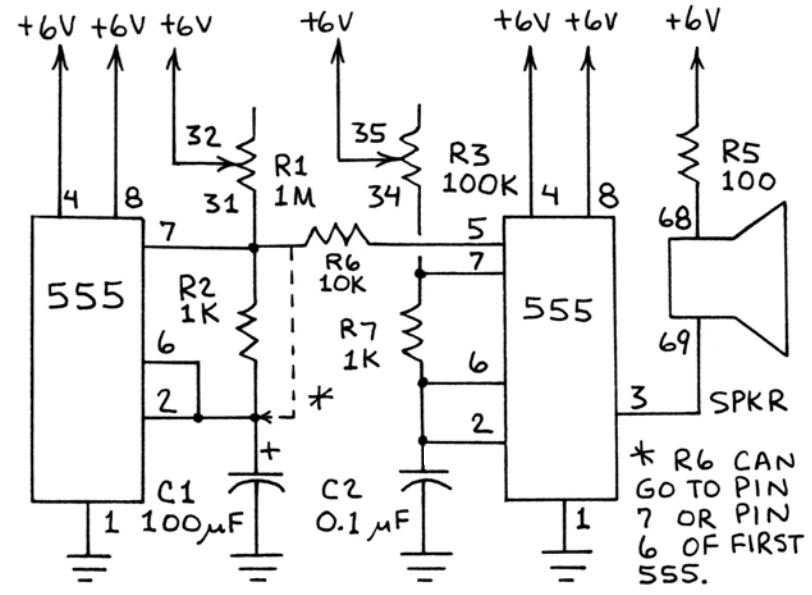
3. TEST THE CIRCUIT

CHECK FOR ERRORS. THEN PUSH THE POWER SWITCH ON AND HAVE FUN CREATING FASCINATING STEPPED TONES BY ADJUSTING CONSOLE POTS R1 AND R3. INCREASE C1 AND C2 FOR NEW EFFECTS.

BUILD A 555 SIREN SYNTHESIZER

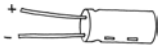
YOU WILL MODIFY THE SOUND SYNTHESIZER (ABOVE) TO CREATE SIREN AND WARBLE SOUNDS.

CIRCUIT DIAGRAM

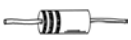


PARTS YOU WILL NEED

SOUND SYNTHESIZER ABOVE PLUS:



C1-100 UF



R6-10K (BRN-BLK-ORG)
R7-1K (BRN-BLK-RED)

2. MODIFY THE SOUND SYNTHESIZER

1. ☐ PUSH THE POWER SWITCH OFF.
2. ☐ REMOVE OLD C1.
3. ☐ INSERT NEW C1 ACROSS K2 (+) AND J2 (-).
4. ☐ REMOVE RED WIRE AT L3-K11.
5. ☐ REMOVE WHT WIRE AT K20-L20.
6. ☐ INSERT R7 ACROSS K20 AND L20.
7. ☐ INSERT R6 ACROSS L10 AND M17.
8. ☐ CONNECT K13 AND L18 (WHT WIRE).
9. ☐ MOVE BLUE WIRE AT L19 TO K19.

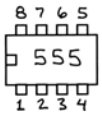
3. TEST THE CIRCUIT

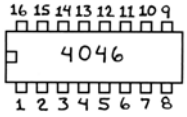
CHECK FOR ERRORS. ROTATE BOTH POTS TOWARD THE RIGHT AND WELL PAST CENTER. PUSH THE POWER SWITCH ON AND ADJUST THE POTS FOR VARIOUS SIREN AND WARBLE EFFECTS.

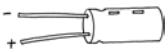
4046 PHASE-LOCKED LOOP CIRCUITS: BUILD A TONE BURSTER

THE 4046 PHASE-LOCKED LOOP IS A COMBINATION ANALOG-DIGITAL IC WITH MANY APPLICATIONS IN SYNTHESIZING SOUND. YOU WILL USE A 555 AND 4046 TO BUILD A CIRCUIT THAT EMITS AN ADJUSTABLE SERIES OF TONE BURSTS.

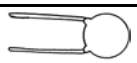
PARTS YOU WILL NEED



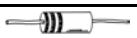




C1-1 UF

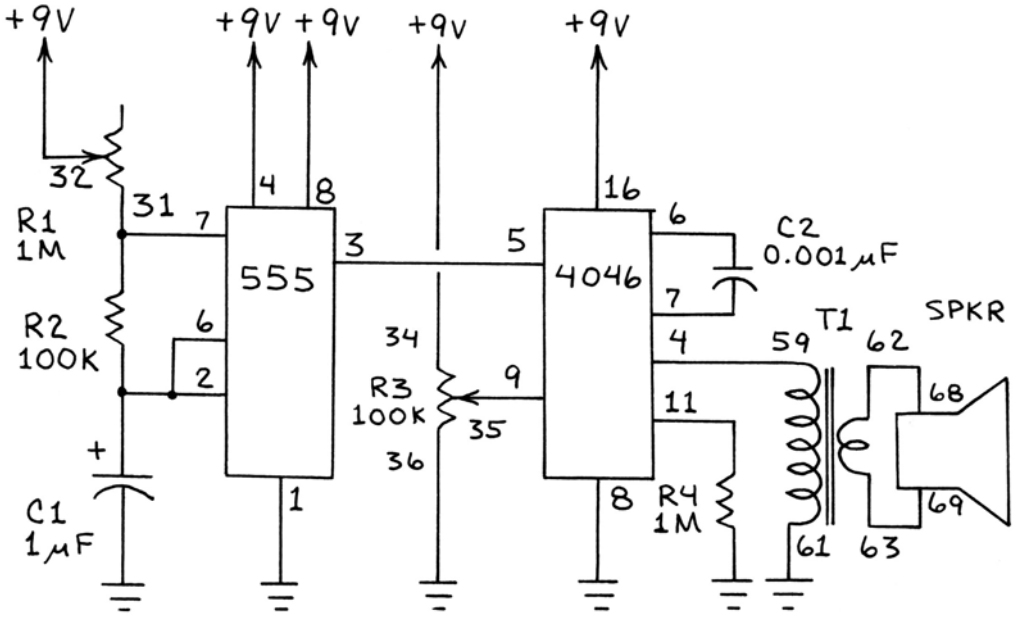


C2-0.001 UF (102)



R2-100K (BRN-BLK-YEL)
R4-1M (BRN-BLK-GRN)

CIRCUIT DIAGRAM



1M CONSOLE POT (R1): CONTROLS THE REPETITION RATE OF THE TONE BURSTS.

10K CONSOLE POT (R3): CONTROLS THE FREQUENCY OF THE TONE WITHIN EACH BURST.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 555 ACROSS SLOT 1 (PIN 1 AT J5).
3. ☐ INSERT 4046 ACROSS SLOT 3 (PIN 1 AT J15).
4. ☐ INSERT C1 ACROSS K2 (+) AND J2 (-).
5. ☐ INSERT C2 ACROSS O12 AND P12.
6. ☐ INSERT R2 ACROSS K10 AND L10.
7. ☐ INSERT R4 ACROSS O17 AND GROUND.
8. ☐ CONNECT K4 AND L7 (WHT WIRE).
9. ☐ CONNECT M4 AND J7 (WHT WIRE).
10. ☐ CONNECT L4 AND N11 (WHT WIRE).
11. ☐ CONNECT J1 AND GROUND (WHT WIRE).
12. ☐ CONNECT J10 AND V6 (+9V) (RED WIRE).
13. ☐ CONNECT Q11 AND GROUND (WHT WIRE).
14. ☐ CONNECT J20 AND V6 (+9V) (WHT WIRE).
15. ☐ CONNECT SPRING 31 TO K7 (RED WIRE).
16. ☐ CONNECT SPRING 32 TO V6 (+9V) (BLU WIRE).
17. ☐ CONNECT SPRING 34 TO V6 (+9V) (BLU WIRE).
18. ☐ CONNECT SPRING 35 TO Q17 (BLU WIRE).
19. ☐ CONNECT SPRING 36 TO GROUND (RED WIRE).
20. ☐ CONNECT SPRING 59 TO M14 (BLU WIRE).
21. ☐ CONNECT SPRING 61 TO GROUND (RED WIRE).
22. ☐ CONNECT SPRINGS 62 AND 68 (RED WIRE).
23. ☐ CONNECT SPRINGS 63 AND 69 (RED WIRE).

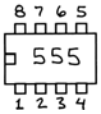
2. TEST THE CIRCUIT

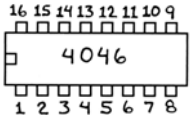
CHECK YOUR WIRING FOR ERRORS. ROTATE THE 1M AND 100K CONSOLE POTS TO THEIR MID-POINTS. PUSH THE POWER SWITCH ON. THE SPEAKER WILL EMIT A SERIES OF TONE BURSTS. ADJUST THE 1M CONSOLE POT (R1) TO CHANGE THE RATE OF THE TONE BURSTS. ADJUST THE 100K CONSOLE POT (R3) TO CHANGE THE FREQUENCY OF THE TONE WITHIN EACH BURST. FOR REAL FUN, INSERT A 100 UF CAPACITOR ACROSS O20 (+) AND GROUND (-). CAREFULLY ADJUST R3 TO CHANGE THE TONE BURSTS TO CHIRPS. NEXT, ROTATE R1 TO THE FAR RIGHT. ADJUST R1 AND R2 TO CREATE VERY SLOW RISING OR FALLING TONES.

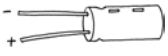
BUILD A FULLY ADJUSTABLE SIREN

THE 4046 IS IDEAL FOR DESIGNING SIREN CIRCUITS. YOU WILL BUILD A FULLY ADJUSTABLE SIREN USING A 555 AND A 4046. YOU WILL USE THE THREE CONSOLE POTS TO ADJUST THE SIREN'S REPETITION RATE, BALANCE AND PITCH.

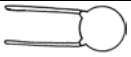
PARTS YOU WILL NEED



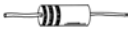




C1-10 UF, C2-1 UF

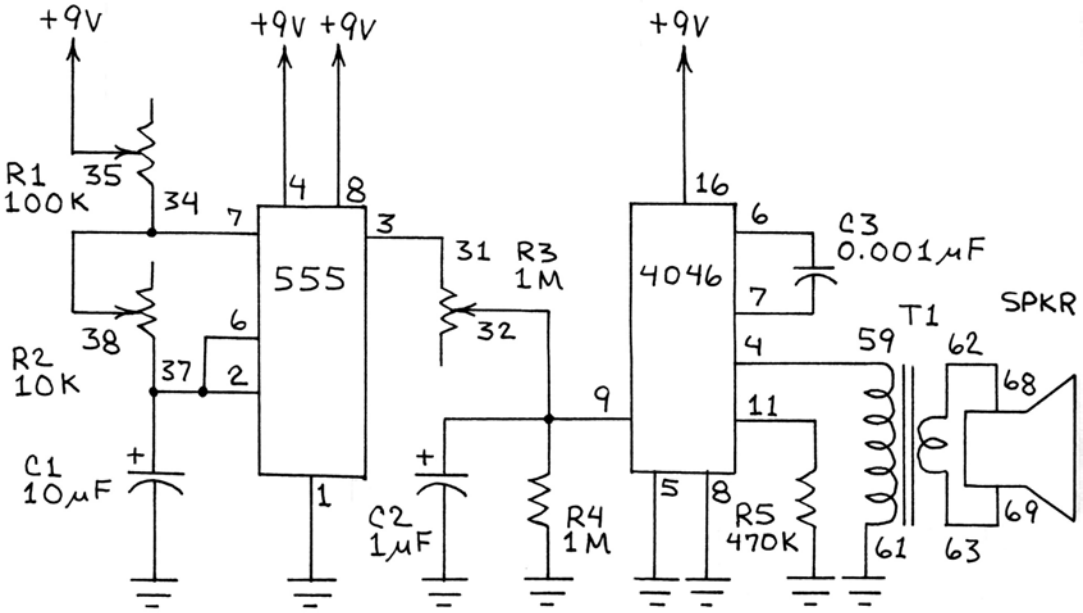


C3-0.001 (102)



R4-1M (BRN-BLK-GRN)
R5-470K (YEL-VIO-YEL)

CIRCUIT DIAGRAM



100K CONSOLE POT (R1): CONTROLS THE NUMBER OF CYCLES PER SECOND.

10K CONSOLE POT (R2): CONTROLS BALANCE OF THE UP-DOWN TONE.

1M CONSOLE POT (R3): CONTROLS PITCH OF THE SIREN.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 555 ACROSS SLOT 1 (PIN 1 AT J5).
3. ☐ INSERT 4046 ACROSS SLOT 3 (PIN 1 AT J15).
4. ☐ INSERT C1 ACROSS K2 (+) AND J2 (-).
5. ☐ INSERT C2 ACROSS Q20 (+) AND GROUND (-).
6. ☐ INSERT C3 ACROSS 012 AND P12.
7. ☐ INSERT R4 ACROSS Q17 AND GROUND.
8. ☐ INSERT R5 ACROSS 020 AND GROUND.
9. ☐ CONNECT K4 AND L7 (WHT WIRE).
10. ☐ CONNECT M4 AND J7 (WHT WIRE).
11. ☐ CONNECT J1 AND GROUND (WHT WIRE).
12. ☐ CONNECT J10 AND V6 (+9V) (RED WIRE).
13. ☐ CONNECT Q11 AND GROUND (WHT WIRE).
14. ☐ CONNECT N11 AND GROUND (WHT WIRE).
15. ☐ CONNECT J20 AND V6 (+9V) (WHT WIRE).
16. ☐ CONNECT SPRING 31 TO L1 (BLU WIRE).
17. ☐ CONNECT SPRING 32 TO Q18 (BLU WIRE).
18. ☐ CONNECT SPRING 34 TO K9 (RED WIRE).
19. ☐ CONNECT SPRING 35 TO V6 (+9V) (BLU WIRE).
20. ☐ CONNECT SPRING 37 TO L10 (BLU WIRE).
21. ☐ CONNECT SPRING 38 TO K10 (BLU WIRE).
22. ☐ CONNECT SPRING 59 TO M11 (BLU WIRE).
23. ☐ CONNECT SPRING 61 TO GROUND (RED WIRE).
24. ☐ CONNECT SPRINGS 62 AND 68 (RED WIRE).
25. ☐ CONNECT SPRINGS 63 AND 69 (RED WIRE).

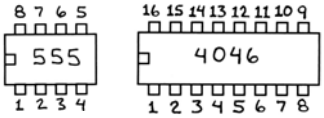
2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. ROTATE ALL THREE CONSOLE POTS TO THEIR MID-POINTS. PUSH THE POWER SWITCH ON. THE SPEAKER WILL EMIT A SIREN-LIKE SOUND. ADJUST THE 100K CONSOLE POT (R1) TO CHANGE THE REPETITION RATE OF THE UP-DOWN TONE. ADJUST THE 10K CONSOLE POT (R2) TO CONTROL THE RELATIVE DURATION OF THE UP AND DOWN SIDE OF EACH SIREN CYCLE. ADJUST THE 1M CONSOLE POT (R3) TO CHANGE THE PITCH OF THE SIREN.

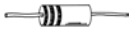
BUILD A FREQUENCY METER

YOU WILL BUILD A SIMPLE ANALOG FREQUENCY METER. AS THE FREQUENCY OF A SIGNAL FROM A 555 OSCILLATOR IS INCREASED, THE METER READING WILL ALSO INCREASE.

PARTS YOU WILL NEED

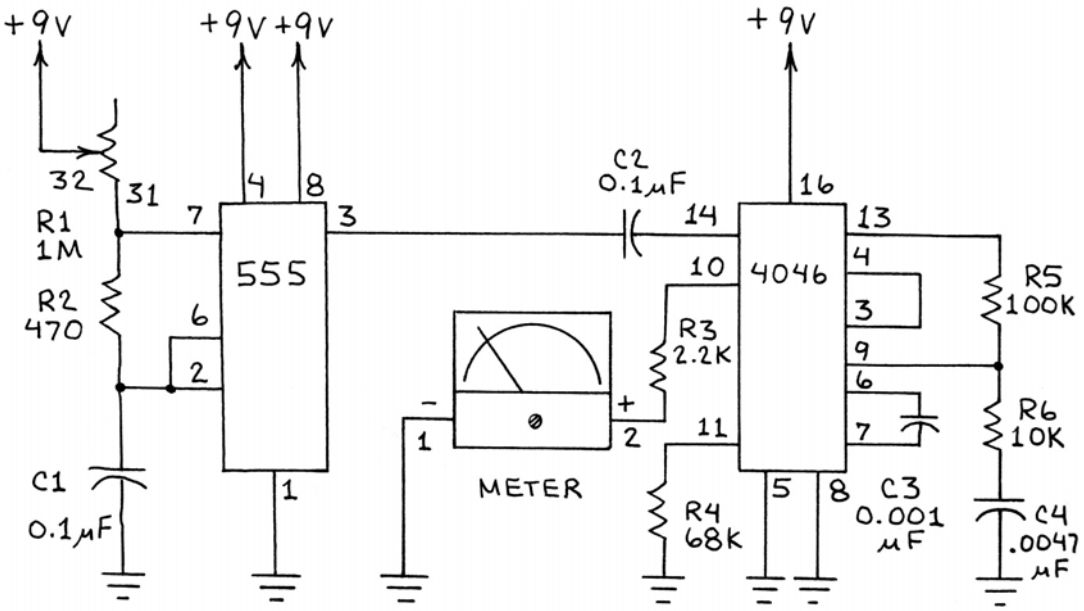


C1, C2–0.1 UF (104)
C3–0.001 UF (102)
C4–0.0047 UF (472)



R2–470 (YEL-VIO-BRN)
R3–2.2K (RED-RED-RED)
R4–68K (BLU-GRY-ORG)
R5–100K (BRN-BLK-YEL)
R6–10K (BRN-BLK-ORG)

CIRCUIT DIAGRAM



1M CONSOLE POT (R1): CONTROLS FREQUENCY OF THE INPUT SIGNAL.

REPLACE R1 WITH PHOTORESISTOR TO MAKE A LIGHT METER.

CONNECT THE TRANSFORMER AND SPEAKER TO 555 (PIN 3) AND GROUND TO HEAR THE TONE.

1. BUILD THE CIRCUIT

1. ☐ PUSH THE POWER SWITCH TO OFF.
2. ☐ INSERT 555 ACROSS SLOT 1 (PIN 1 AT J5).
3. ☐ INSERT 4046 ACROSS SLOT 3 (PIN 1 AT J15).
4. ☐ INSERT C1 ACROSS J2 AND K2.
5. ☐ INSERT C2 ACROSS H18 AND L18.
6. ☐ INSERT C3 ACROSS O12 AND P12.
7. ☐ INSERT C4 ACROSS T18 AND GROUND.
8. ☐ INSERT R2 ACROSS K10 AND L10.
9. ☐ INSERT R3 ACROSS P20 AND P22.
10. ☐ INSERT R4 ACROSS O18 AND GROUND.
11. ☐ INSERT R5 ACROSS M17 AND Q17.
12. ☐ INSERT R6 ACROSS Q20 AND T20.
13. ☐ CONNECT K4 AND L7 (WHT WIRE).
14. ☐ CONNECT M4 AND J7 (WHT WIRE).
15. ☐ CONNECT J1 AND GROUND (WHT WIRE).
16. ☐ CONNECT J10 AND V6 (+9V) (RED WIRE).
17. ☐ CONNECT Q11 AND GROUND (WHT WIRE).
18. ☐ CONNECT L11 AND M11 (WHT WIRE).
19. ☐ CONNECT L4 AND H16 (RED WIRE).
20. ☐ CONNECT N11 AND GROUND (WHT WIRE).
21. ☐ CONNECT J20 AND V6 (+9V) (WHT WIRE).
22. ☐ CONNECT SPRING 31 TO K7 (BLU WIRE).
23. ☐ CONNECT SPRING 32 TO V6 (+9V) (BLU WIRE).
24. ☐ CONNECT SPRING 1 TO GROUND (BLU WIRE).
25. ☐ CONNECT SPRING 2 TO P25 (BLU WIRE).

2. TEST THE CIRCUIT

CHECK YOUR WIRING FOR ERRORS. ROTATE THE 1M CONSOLE POT (R1) ALL THE WAY TO THE LEFT. PUSH THE POWER SWITCH ON. SLOWLY ROTATE R1 TO THE RIGHT. THE METER NEEDLE WILL BEGIN TO MOVE TO THE RIGHT TO INDICATE THE INCREASED FREQUENCY FROM THE 555. VERY SLIGHT FLAWS IN R1 MAY CAUSE THE NEEDLE TO JUMP WHEN R1 IS ROTATED.