9. 100 ELECTRONIC CIRCUITS

HERE'S A COLLECTION OF 100 ELECTRONIC CIRCUITS. I'VE ASSEMBLED EACH CIRCUIT TO MAKE SURE ALL OF THEM WORK.

☐ SELECTING AND SUBSTITUTING COMPONENTS — YOU CAN FIND MOST OF THE COMPONENTS AT RADIO SHACK STORES. SAVE TIME AND MAKE A LIST OF WHAT YOU NEED BEFORE YOU VISIT RADIO SHACK. (YOU CAN FIND CURRENT CATALOG NUMBERS IN THE LATEST RADIO SHACK CATALOG.) IF A COMPONENT IS UNAVAILABLE, TRY ELSEWHERE. SOMETIMES YOU CAN SUBSTITUTE COMPONENTS. FOR EXAMPLE, IT'S OFTEN OK TO SUBSTITUTE NPN SWITCHING TRANSISTORS FOR ONE ANOTHER (2N3904 FOR 2N2222, ETC.). NEARBY VALUES OF RESISTORS AND CAPACITORS CAN OFTEN BE USED (1.2 K FOR 1K RESISTOR, 0.33 μF FOR 0.47 μF CAPACITOR, ETC.). ALWAYS FOLLOW APPROPRIATE VOLTAGE AND POWER RATINGS!

☐ WHEN A CIRCUIT DOESN'T WORK — MAKE SURE THE CIRCUIT IS RECEIVING ADEQUATE POWER. IF IT IS OR IF YOU SMELL OR FEEL A HOT COMPONENT, IMMEDIATELY DISCONNECT THE POWER AND FOLLOW THESE STEPS: (1) RECHECK ALL CONNECTIONS. (IS A WIRE MISSING? IS AN IC PIN BENT? IS A SOLDER CONNECTION BAD? IS A WIRE "SHORTED"? IS A DIODE BACKWARDS?) (2) IS A COMPONENT DEFECTIVE? (3) SOMETIMES, ESPECIALLY WHEN POWER SUPPLY LEADS ARE MORE THAN SIX INCHES LONG, IC CIRCUITS WILL WORK IMPROPERLY OR NOT AT ALL UNLESS YOU CONNECT A 0.1 μF CAPACITOR ACROSS THE POWER SUPPLY PINS OF EACH CHIP. IT MAY ALSO BE NECESSARY TO CONNECT A 1 TO 10 μF CAPACITOR ACROSS THE POWER LEADS WHERE THEY ENTER THE BOARD. (4) DOES THE PUBLISHED CIRCUIT CONTAIN AN ERROR?

☐ SAFETY FIRST — BE SURE TO FOLLOW APPROPRIATE PRECAUTIONS WHEN WORKING WITH AC LINE POWERED CIRCUITS. BE CAREFUL WHEN SOLDERING. CIRCUITS WITH SPEAKERS CAN PRODUCE VERY LOUD SOUNDS. KEEP YOUR DISTANCE, AND DON'T USE HEADPHONES.

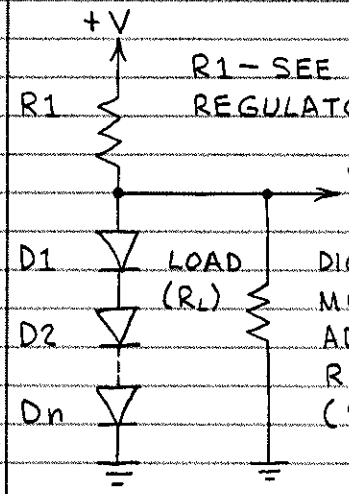
☐ GOING FURTHER — TRY EXPERIMENTING WITH THE VALUES OF COMPONENTS IN RC CIRCUITS (P. 37). TRY SUBSTITUTING OTHER OUTPUT DEVICES IN CIRCUITS THAT DRIVE A RELAY, PIEZO BUZZER, ETC. (BE SURE TO FOLLOW VOLTAGE AND CURRENT RATINGS. USE OHM'S LAW AND, IF NECESSARY, ADD A SERIES RESISTOR TO REDUCE CURRENT.) BEFORE BUILDING A PERMANENT VERSION OF A CIRCUIT, ALWAYS ASSEMBLE AND TEST A BREADBOARD VERSION. FINALLY, BE SURE TO BUY RADIO SHACK'S CURRENT "SEMICONDUCTOR REFERENCE GUIDE" AND "ENGINEER'S NOTEBOOK." FOR MORE ADVANCED CIRCUITS AND INFORMATION ABOUT NEW DEVELOPMENTS, READ MY COLUMN ("THE ELECTRONICS SCIENTIST") IN COMPUTERS & ELECTRONICS.

DIODE CIRCUITS

THE VARIOUS KINDS OF DIODES HAVE MANY APPLICATIONS. HERE ARE SOME TYPICAL CIRCUITS:

SMALL SIGNAL DIODES AND RECTIFIERS

☐ VOLTAGE REGULATOR



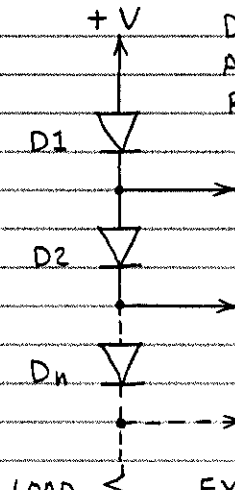
R1 – SEE ZENER DIODE REGULATOR (P. 103)

$V_{OUT} = n \times 0.6V$

DIODE(S) AND R1 MUST HAVE ADEQUATE POWER RATING (SEE P. 103)

ONE OR MORE SILICON DIODES CAN REGULATE A VOLTAGE IN 0.6 VOLT STEPS.

☐ VOLTAGE DROPPER



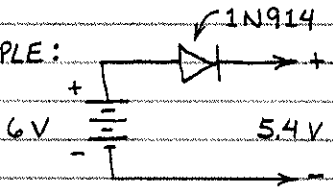
DIODES MUST HAVE ADEQUATE POWER RATING ($P = V \times I$)

V - 0.6

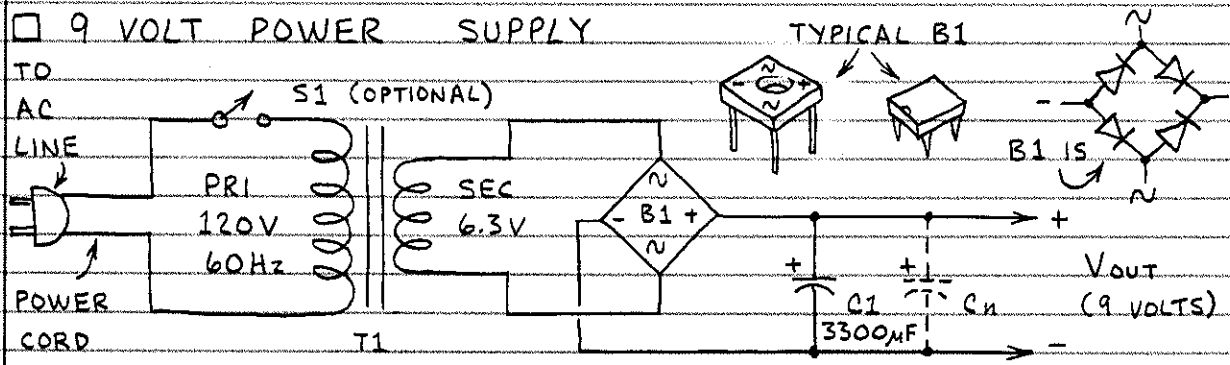
V - 1.2

V - (n x 0.6 V)

EXAMPLE:



☐ 9 VOLT POWER SUPPLY

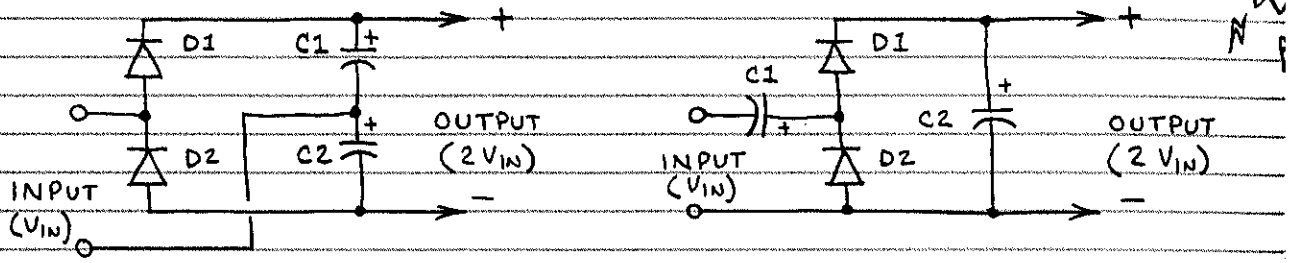


THIS IS A BASIC AC LINE OPERATED 9 VOLT POWER SUPPLY. FOR LOW RIPPLE (SUPERIMPOSED AC AT V_{OUT}), USE LARGE VALUE FOR C1. (OK TO ADD ONE OR MORE CAPACITORS (Cn) IN PARALLEL WITH C1 FOR MORE CAPACITANCE.) CAPACITORS MUST HAVE A DC WORKING VOLTAGE (WVDC) OF AT LEAST 12 VOLTS. RECTIFIER BRIDGE B1 MUST HAVE PEAK INVERSE VOLTAGE (P.I.V) OF AT LEAST 12 VOLTS. T1 AND B1 MUST HAVE ADEQUATE POWER AND CURRENT RATINGS. (USE OHMS LAW...)

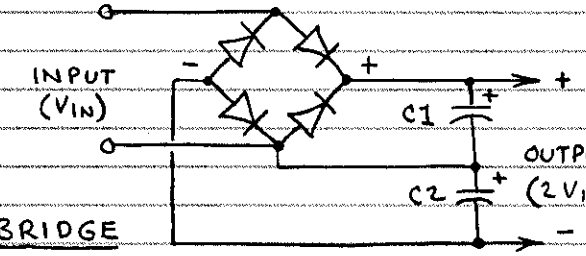
CAUTION: YOU MUST INSULATE OR ENCLOSE ALL EXPOSED AC LINE CONNECTIONS! THE POWER CORD MUST BE UNPLUGGED WHEN YOU ASSEMBLE OR SERVICE THE CIRCUIT!

CAUTION: THESE CIRCUITS CAN PRODUCE HIGH VOLTAGES

☐ VOLTAGE DOUBLERS

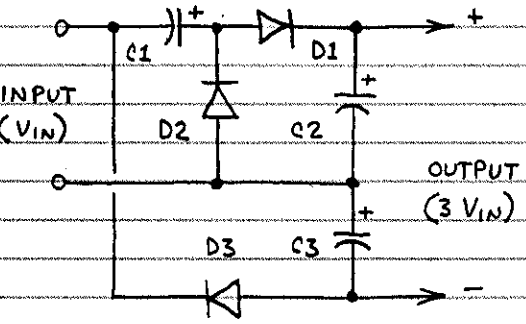


THESE CIRCUITS APPROXIMATELY DOUBLE AN INCOMING AC VOLTAGE. THE OUTPUT IS DC. USE CAPACITORS AND DIODES RATED FOR TWICE THE INPUT VOLTAGE. OUTPUT RIPPLE (∿∿) CAN BE REDUCED BY USING LARGE VALUES FOR C1 AND C2.



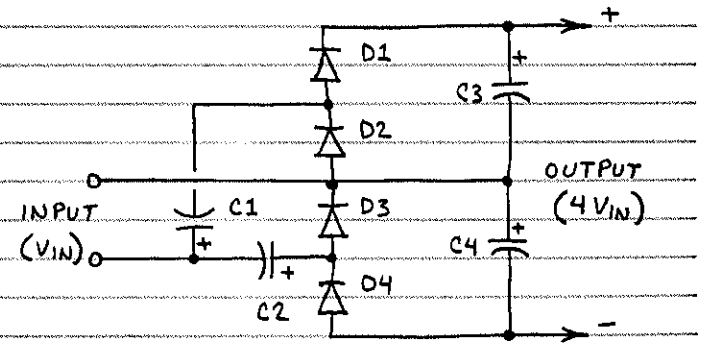
THE BRIDGE DOUBLER IS MORE EFFICIENT THAN THE CONVENTIONAL AND CASCADE DOUBLERS. SINCE 4-DIODE BRIDGE RECTIFIERS ARE AVAILABLE, IT'S EASY TO MAKE.

☐ VOLTAGE TRIPLER



TRIPLES AND CONVERTS TO DC AN INCOMING AC VOLTAGE. C2, D1, D2 AND D3 RATED AT >2 V_{IN}.

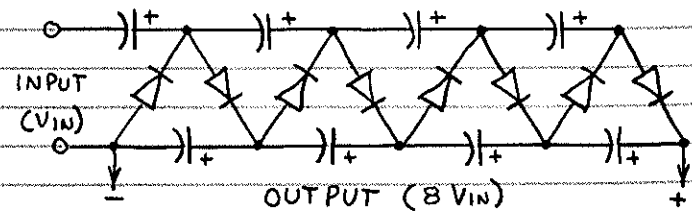
☐ VOLTAGE QUADRUPLER



QUADRUPLES AND CONVERTS TO DC AN INCOMING AC VOLTAGE. ALL COMPONENTS RATED AT >2 V_{IN}.

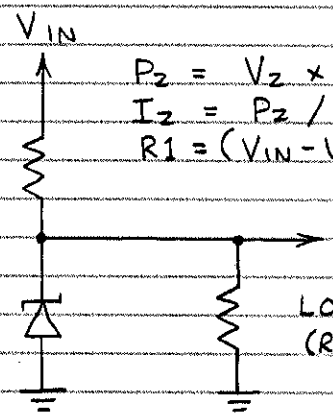
☐ CASCADE MULTIPLIER

ADD MORE STAGES FOR MORE MULTIPLICATION. ALL COMPONENTS RATED AT >2 V_{IN}.



ZENER DIODE CIRCUITS

☐ VOLTAGE REGULATOR



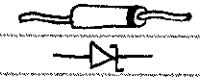
$P_Z = V_Z \times I_L$

$I_Z = P_Z / V_Z$

$R1 = (V_{IN} - V_Z) / I$

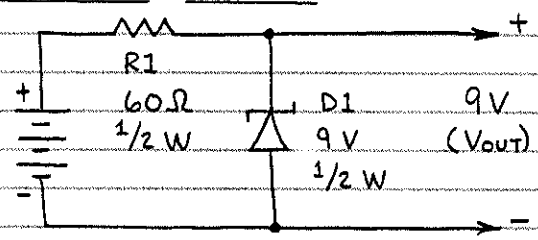
I_L = MAXIMUM LOAD CURRENT
I_Z = MAXIMUM ZENER CURRENT
I = CURRENT THROUGH R1
V_Z = ZENER DIODE VOLTAGE
P_Z = ZENER DIODE POWER

THIS CIRCUIT SUPPLIES A STEADY VOLTAGE (V_{OUT}) TO A LOAD FROM AN UNREGULATED SUPPLY (LIKE A BATTERY). V_{IN} CAN VARY BUT MUST BE AT LEAST 1 VOLT ABOVE DESIRED V_{OUT}. I_L CAN VARY FROM 0 MA TO PLANNED MAXIMUM VALUE. I DOES NOT CHANGE IF I_L FALLS TO 0 MA. SINCE $I = I_L + I_Z$, I_Z RISES AS I_L FALLS. IN OTHER WORDS, THE REGULATOR ALWAYS USES THE SAME CURRENT, EVEN WHEN THE LOAD IS REMOVED. CAUTION: D1 AND R1 MUST HAVE PROPER POWER RATING. USE OHM'S LAW (P. 14).

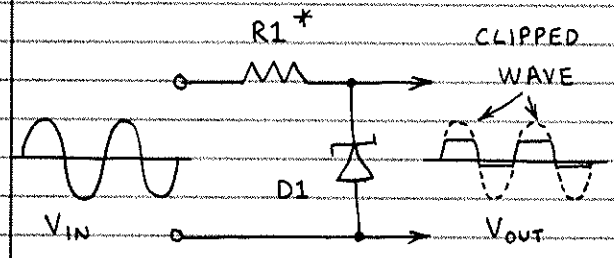


EXAMPLE: A RADIO DRAWS FROM 20 TO 50 MA FROM A 9 VOLT BATTERY. TO POWER IT FROM A 12 VOLT BATTERY, USE A 9 VOLT, 1/2 WATT ZENER DIODE. R1 SHOULD BE CLOSE TO 60 Ω AND RATED FOR AT LEAST 0.15 W.

EXAMPLE CIRCUIT:

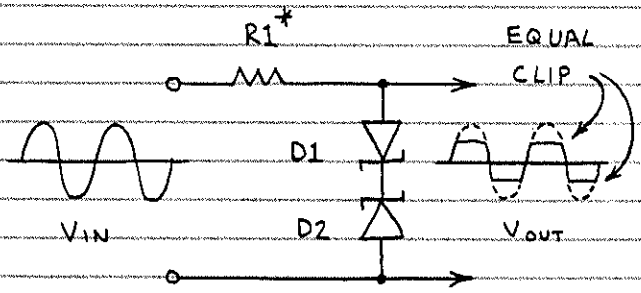


☐ WAVEFORM CLIPPER



THIS CIRCUIT IS HANDY FOR REDUCING AN INCOMING SIGNAL VOLTAGE TO A LOWER, MORE MANAGEABLE LEVEL. IT CAN ALSO CONVERT A SINE OR TRIANGLE WAVE TO AN APPROXIMATION OF A SQUARE WAVE. * R1: SEE ABOVE (LET I = 2 MA MINIMUM).

☐ DUAL WAVEFORM CLIPPER



THIS IS A SYMMETRICAL FORM OF THE ADJACENT CIRCUIT. IT CLIPS BOTH HALVES OF AN INCOMING WAVE EQUALLY (IF V_Z = D1 = D2). USE TO PROTECT SPEAKERS AND PHONES FROM EXCESSIVE SIGNAL LEVELS OR TO MAKE SQUARE WAVES.

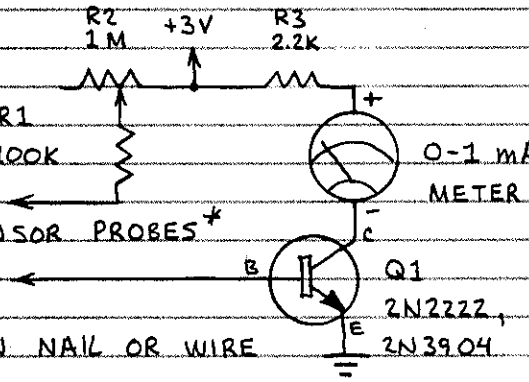
TRANSISTOR CIRCUITS

INTEGRATED CIRCUITS RECEIVE MORE ATTENTION, BUT BOTH BIPOLAR AND FIELD-EFFECT TRANSISTORS HAVE MANY APPLICATIONS.

BIPOLAR TRANSISTOR CIRCUITS

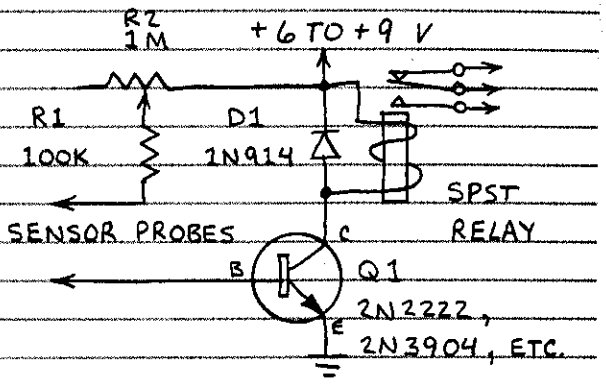
2N2222
2N2907,
ETC.

☐ MOISTURE METER



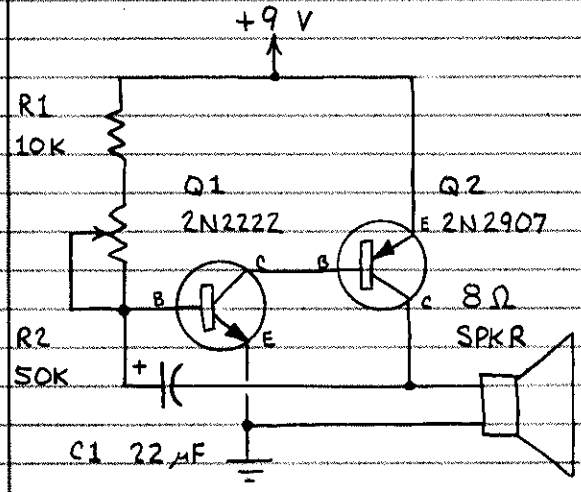
THIS CIRCUIT WILL MEASURE THE MOISTURE LEVEL OF SOIL IN YOUR GARDEN. ADJUST R2 FOR METER READING OF 1 mA. WHEN SOIL MOISTURE IS AT DESIRED LEVEL. METER WILL THEN INDICATE LOWER MOISTURE LEVELS.

☐ MOISTURE ACTUATED RELAY



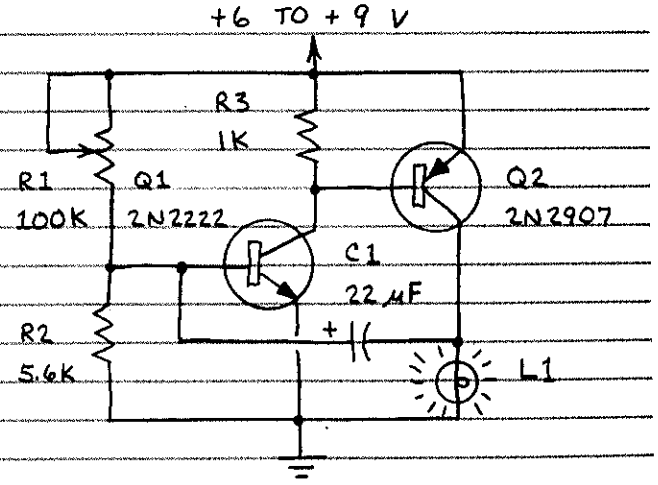
THIS CIRCUIT CLOSES A RELAY (6-9 V, 500 OHM COIL) WHEN MOISTURE LEVEL EXCEEDS A LEVEL SET BY R2. RELAY CONTACTS THEN SWITCH ON A LIGHT OR OTHER DEVICE. CAN DETECT RAIN.

☐ METRONOME



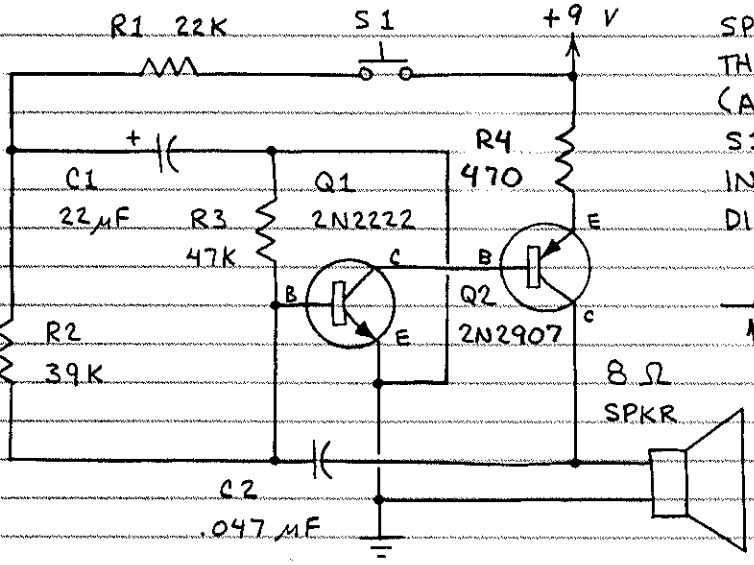
A METRONOME MARKS TIME BY PRODUCING A REGULAR SEQUENCE OF "CLICKS" OR "POCKS." ADJUST THE CLICK RATE BY ADJUSTING R2 OR CHANGING C1's VALUE.

☐ LIGHT FLASHER

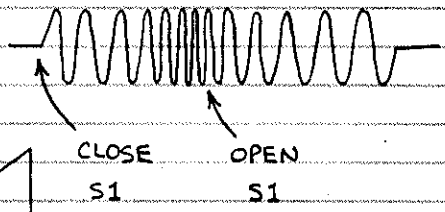


THIS CIRCUIT PRODUCES BRIGHT FLASHES EVERY SECOND OR SO. R1 CONTROLS FLASH RATE. USE NO. 122 OR 222 MINIATURE LAMP FOR L1.

☐ SIREN

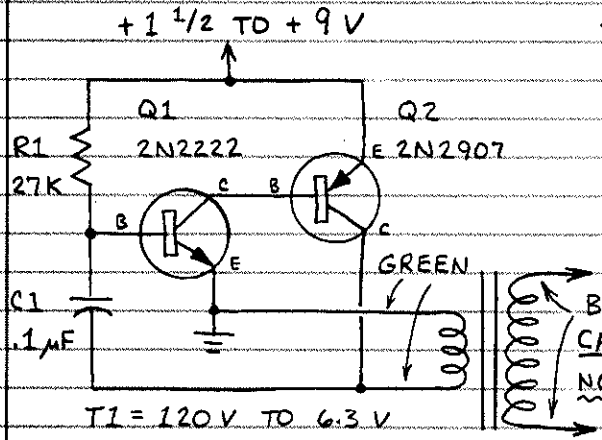


CLOSE S1 AND THE SPEAKER EMITS A TONE THAT RISES IN FREQUENCY (AS C1 CHARGES). OPEN S1 AND THE TONE FALLS IN FREQUENCY (AS C1 DISCHARGES). LIKE THIS:



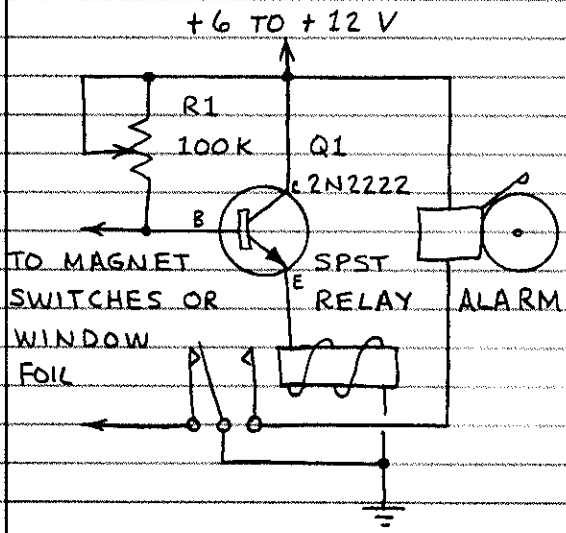
HINT: CHANGE R1 TO CHANGE UP-DOWN TIME.

☐ HIGH VOLTAGE POWER SUPPLY



THIS CIRCUIT PRODUCES 220 VOLT PULSES OF DC WHEN POWERED BY A 9-VOLT BATTERY. IT WILL PRODUCE UP TO 170 VOLTS FROM A FLASHLIGHT CELL (BUT YOU MAY HAVE TO EXPERIMENT WITH C1'S VALUE. THE CIRCUIT WILL POWER ONE OR MORE NEON LAMPS THROUGH A 1M SERIES RESISTOR.

☐ BURGLAR ALARM

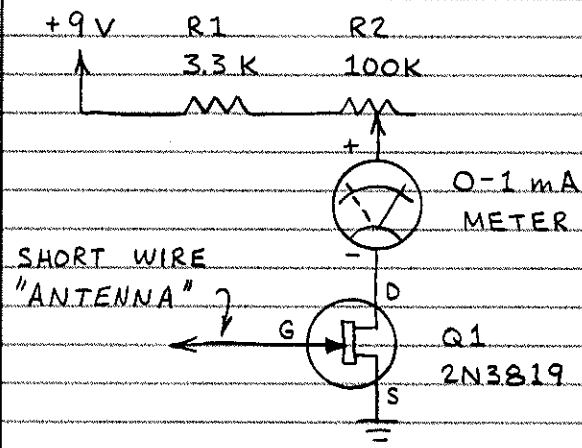


ALARM SOUNDS AND STAYS ON (UNTIL POWER IS DISCONNECTED) WHEN MAGNET SWITCH IS OPENED OR WINDOW FOIL IS BROKEN. R1: SET TO MAXIMUM VALUE. DISCONNECT ONE LEAD TO SWITCHES/FOIL. THEN REDUCE VALUE OF R1 TO JUST PAST POINT WHERE ALARM SOUNDS. CIRCUIT USES ONLY 0.3 MILLIAMPERES AT 6 VOLTS. RELAY: USE 6 V, 500 Ω UNIT WHEN SUPPLY IS 6-9 V. USE 12 V, 1200 Ω UNIT WHEN SUPPLY IS 12 V. NOTE: ASSEMBLE, INSTALL AND CONCEAL THIS SYSTEM WITH CARE.

JUNCTION FET CIRCUITS

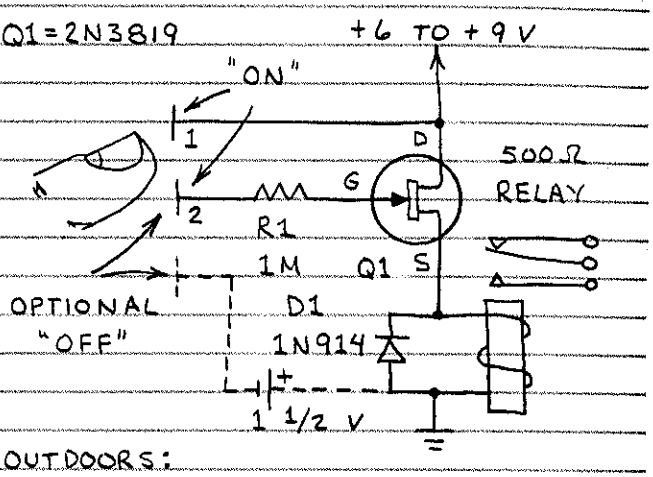
S G D
2N3819

☐ ELECTROMETER



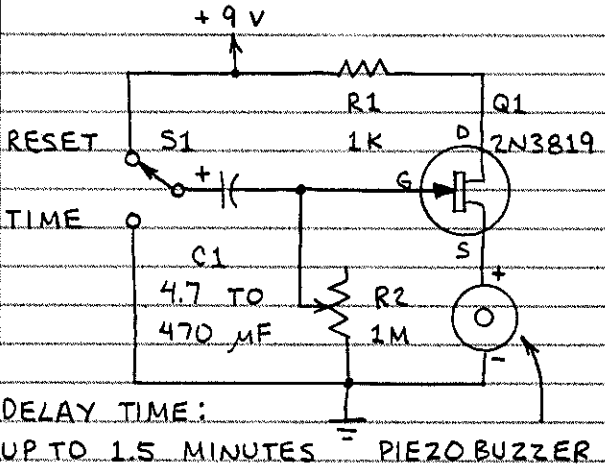
THIS CIRCUIT DETECTS STATIC ELECTRICITY FROM A CHARGED OBJECT (PLASTIC COMB, ETC.) OVER A FOOT AWAY! ADJUST R1 SO METER INDICATES 1 MA. CHARGED OBJECT NEAR "ANTENNA" WILL DECREASE METER READING.

☐ TOUCH SWITCH



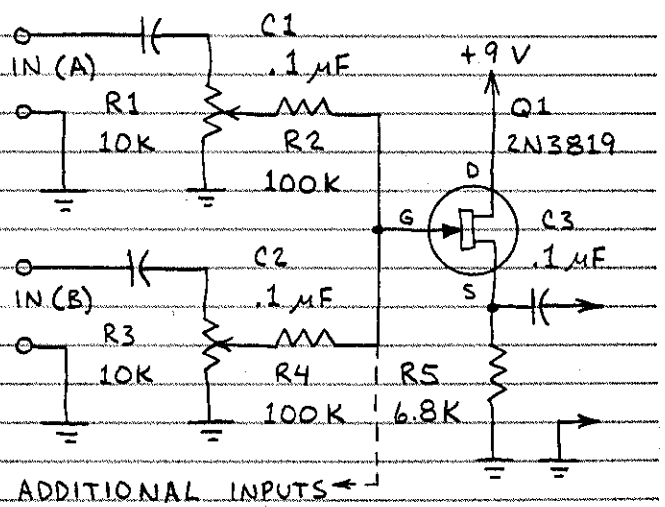
OUTDOORS:
AWAY FROM POWER LINES, BRIEFLY TOUCH "ON" CONTACTS TO ACTUATE RELAY. TOUCH CONTACT 2 ONLY TO DEACTUATE RELAY.
INDOORS:
MAY BE NECESSARY TO INCLUDE OPTIONAL "OFF" CIRCUIT.

☐ TIMER



SET S1 TO "RESET" (BUZZER WILL SOUND). THEN SET S1 TO "TIME." BUZZER WILL BE SILENT UNTIL DELAY IS COMPLETE. BUZZER WILL THEN SOUND. INCREASE C1 OR R1 FOR LONGER DELAYS. REDUCE R2'S RESISTANCE DURING RESET MODE (SPEEDS UP RESET).

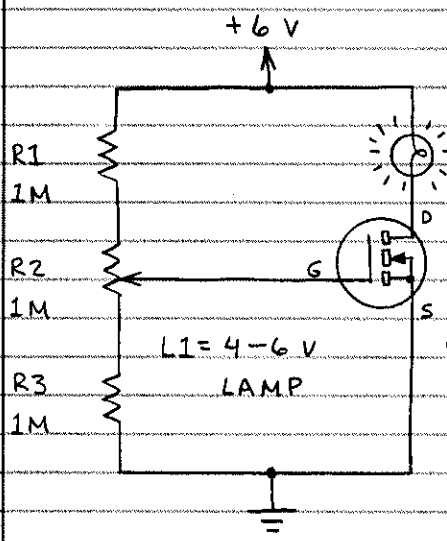
☐ AUDIO MIXER



THIS CIRCUIT ALLOWS TWO (OR MORE) MICROPHONES OR OTHER DEVICES TO BE CONNECTED TO THE SAME AMPLIFIER. R1 AND R3 CONTROL ATTENUATION OF EACH INPUT. THEREFORE R1 AND R3 ARE BALANCE CONTROLS.

POWER MOSFET (DMOS, VMOS, ETC.) CIRCUITS

☐ LINEAR LIGHT DIMMER



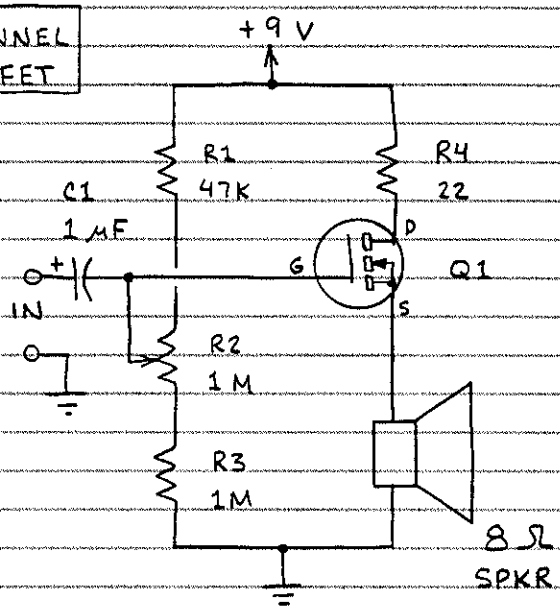
Q1 = N-CHANNEL POWER MOSFET

L1 = 4-6 V LAMP

DO NOT EXCEED POWER RATING OF Q1.

CHANGE SETTING OF R2 TO CHANGE INTENSITY OF LAMP. THIS CIRCUIT SHOWS HOW POWER MOSFET CAN BE USED AS A VARIABLE RESISTOR.

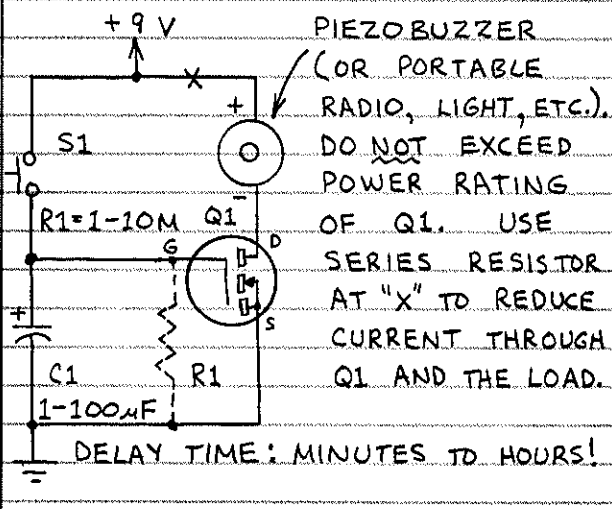
☐ AUDIO AMPLIFIER



USE TO AMPLIFY SIGNALS AND TONES FROM OTHER CIRCUITS. R2 CONTROLS GAIN (VOLUME).

☐ LONG DURATION TIME DELAY CIRCUITS

1. OFF AFTER DELAY

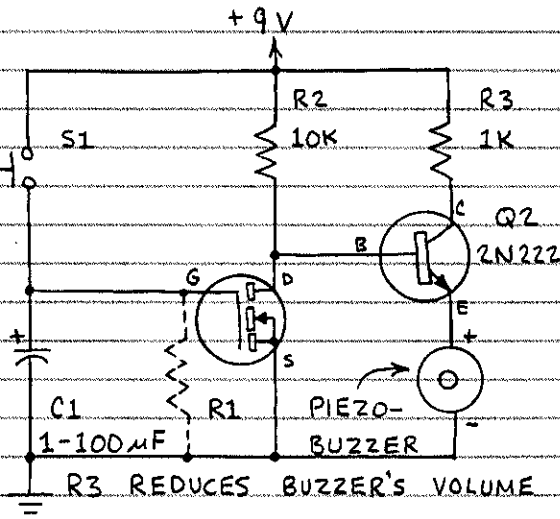


PIEZOBUZZER (OR PORTABLE RADIO, LIGHT, ETC.). DO NOT EXCEED POWER RATING OF Q1. USE SERIES RESISTOR AT "X" TO REDUCE CURRENT THROUGH Q1 AND THE LOAD.

DELAY TIME: MINUTES TO HOURS!

CLOSE AND THEN OPEN S1 TO ACTIVATE BUZZER. AFTER C1 DISCHARGES INTERNALLY OR THROUGH R1 (OPTIONAL), Q1 TURNS OFF AND SILENCES THE BUZZER. LONG DELAYS POSSIBLE.

2. ON AFTER DELAY



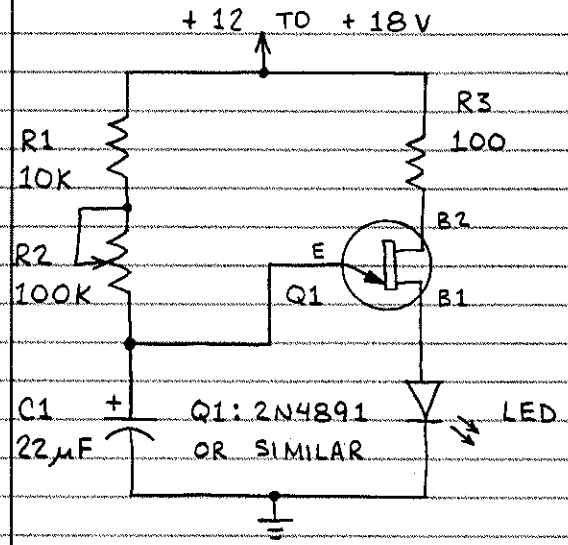
R3 REDUCES BUZZER'S VOLUME

Q2 INVERTS THE STATUS OF Q1. THEREFORE THE BUZZER SOUNDS AFTER THE TIME DELAY IS COMPLETE. INCREASE C1's VALUE TO INCREASE DELAY.

UNIJUNCTION TRANSISTOR CIRCUITS

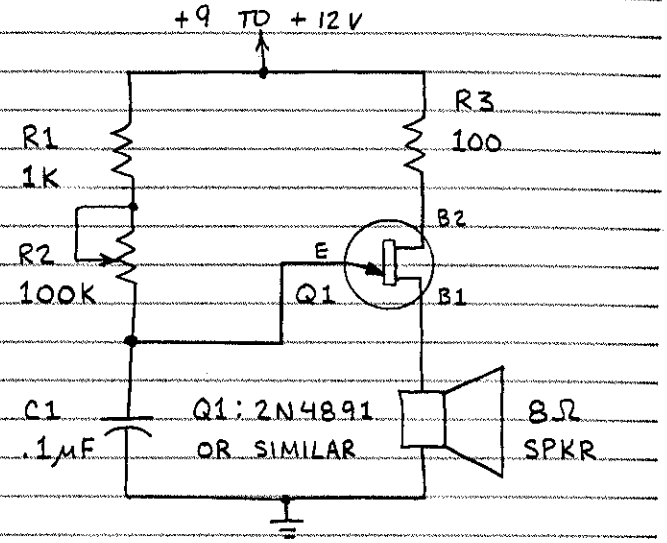
B1 E B2
2N4891

☐ TIME BASE



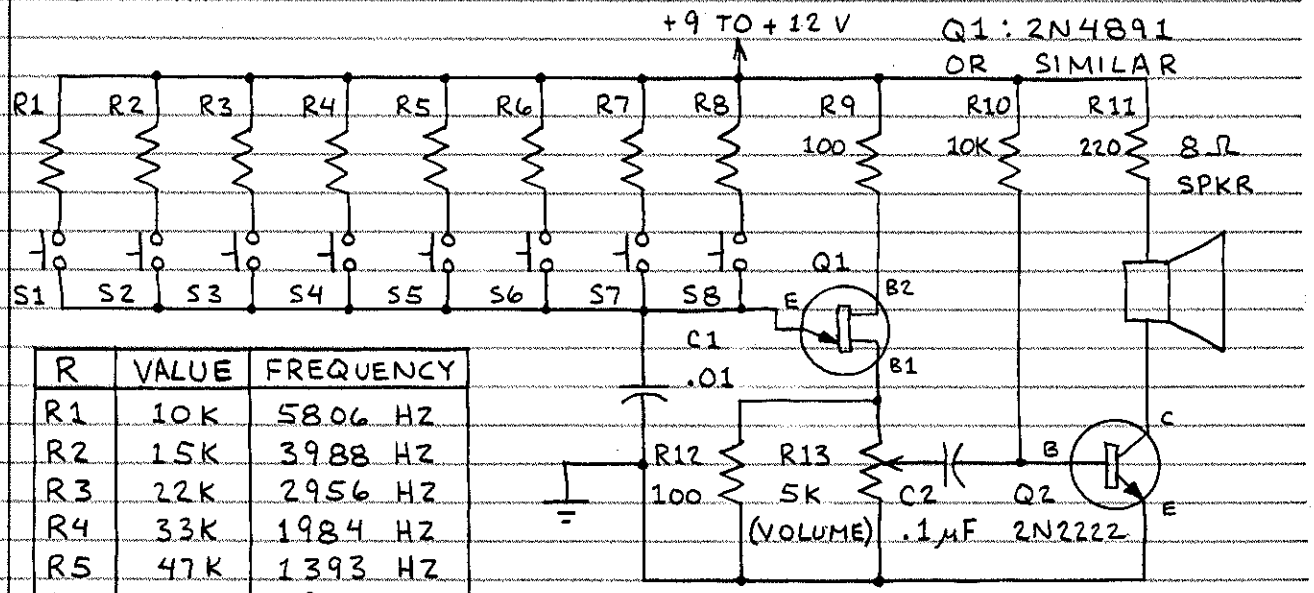
EACH TIME THE UJT (Q1) TURNS ON, THE CHARGE ON C1 IS "DUMPED" THROUGH THE LED. THE LED FLASHES IN RESPONSE. BETWEEN FLASHES, THE LED GLOWS DIMLY. R2 CONTROLS FLASH RATE AND CAN BE SET FOR ONE FLASH PER SECOND (TIME BASE ROLE).

☐ TONE GENERATOR



THIS CIRCUIT IS IDENTICAL IN PRINCIPLE TO THE ADJACENT CIRCUIT. C1 IS MUCH SMALLER TO SPEED UP THE CHARGE-DISCHARGE CYCLE. THE RESULT IS AN AUDIO FREQUENCY TONE WHICH IS EMITTED BY THE SPEAKER. THIS CIRCUIT CAN BE EXPANDED (SEE BELOW).

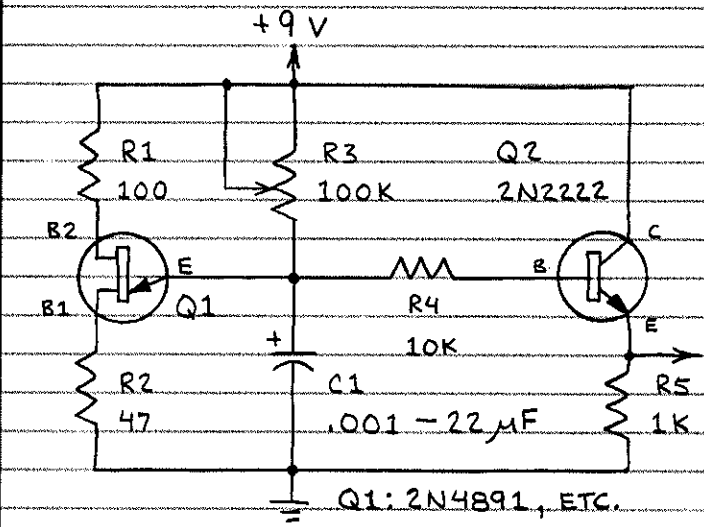
☐ ORGAN



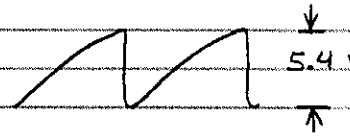
R	VALUE	FREQUENCY
R1	10K	5806 HZ
R2	15K	3988 HZ
R3	22K	2956 HZ
R4	33K	1984 HZ
R5	47K	1393 HZ
R6	68K	941 HZ
R7	100K	583 HZ
R8	150K	430 HZ

TABLE SHOWS TYPICAL FREQUENCIES. CHANGE C1 TO ALTER THE OVERALL FREQUENCY RANGE.

☐ RAMP GENERATOR

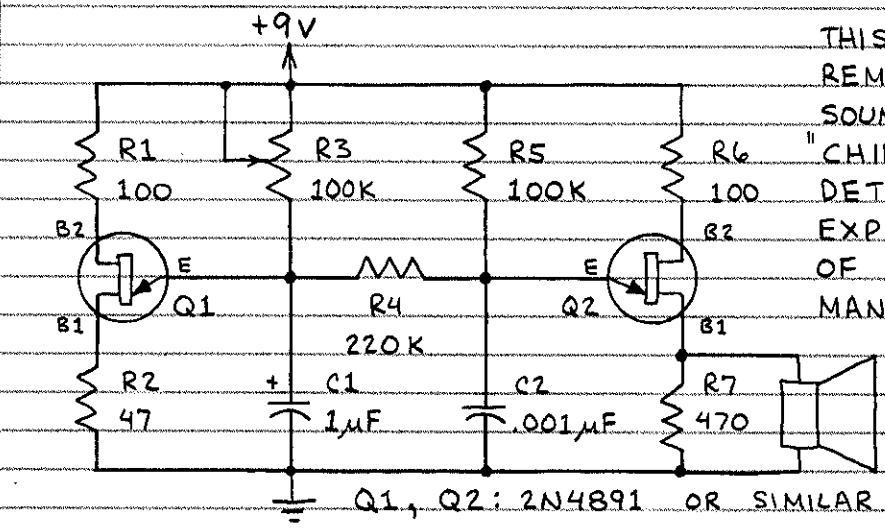


Q2 SAMPLES THE VOLTAGE ON C1 AND OUTPUTS IT AS A RAMP (OR "SAWTOOTH" WAVE). R3 CONTROLS THE RATE AT WHICH RAMPS ARE PRODUCED.



RAMPS SUPPLY GRADUALLY INCREASING VOLTAGE TO MANY KINDS OF CIRCUITS.

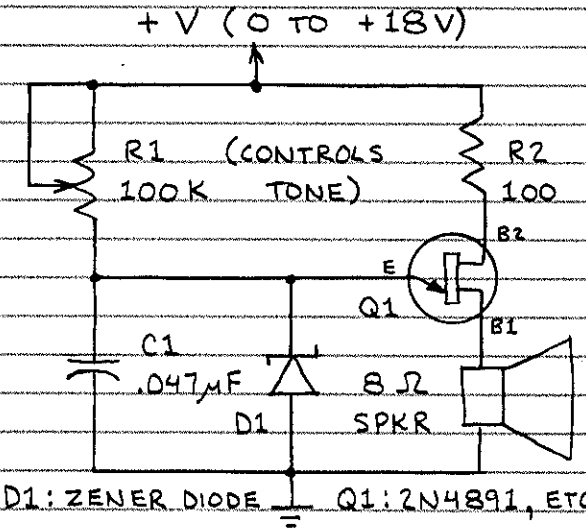
☐ CHIRP GENERATOR



THIS CIRCUIT PRODUCES A REMARKABLE VARIETY OF SOUNDS. AS SHOWN, IT "CHIRPS" AT A RATE DETERMINED BY R3. EXPERIMENT WITH VALUES OF C1, R5 AND C2 FOR MANY OTHER EFFECTS.

PIEZO TWEETER SPEAKER

☐ VOLTAGE SENSITIVE OSCILLATOR



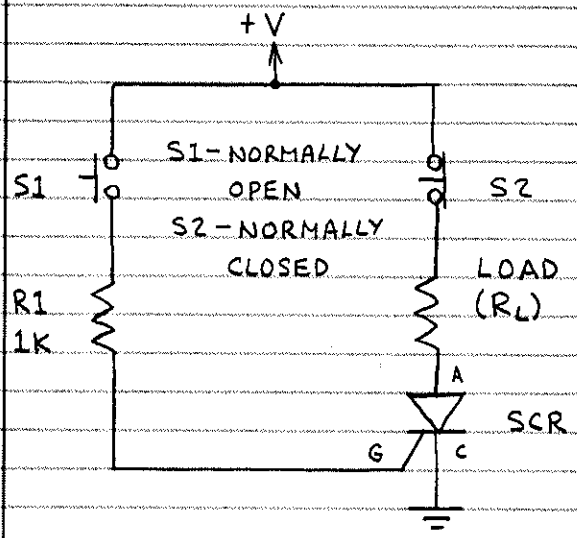
THIS CIRCUIT SOUNDS A TONE WHEN V_{IN} IS BELOW V_Z OF D1. SELECT V_Z OF D1 FOR DESIRED TURN-OFF LEVEL. THIS CIRCUIT CAN BE USED TO INDICATE WHEN VOLTAGE OF A BATTERY (WHICH CAN BE POWERING ANOTHER CIRCUIT) FALLS BELOW A CERTAIN LEVEL. THIS IS AN EXCELLENT EXAMPLE OF A SIMPLE, YET SOPHISTICATED, CIRCUIT.

THYRISTOR CIRCUITS

SILICON CONTROLLED RECTIFIERS AND TRIACS HAVE MANY APPLICATIONS AS SOLID-STATE SWITCHES.

SCR CIRCUITS

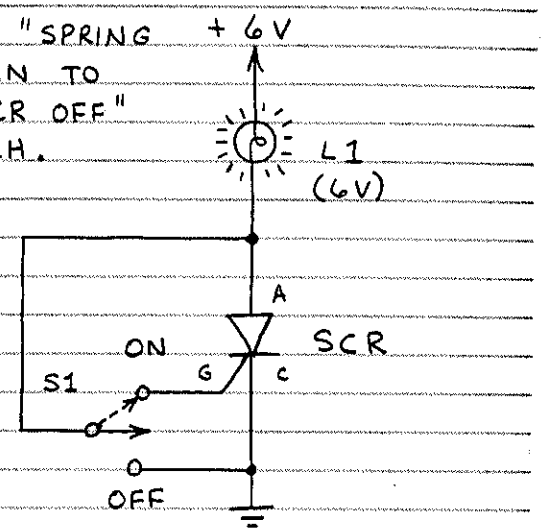
☐ LATCHING SWITCH



CLOSE S1 TO TURN ON THE SCR AND SUPPLY CURRENT TO THE LOAD. THE SCR WILL REMAIN ON AFTER S1 IS OPENED UNLESS THE LOAD IS A DC MOTOR OR UNTIL S2 IS BRIEFLY OPENED.

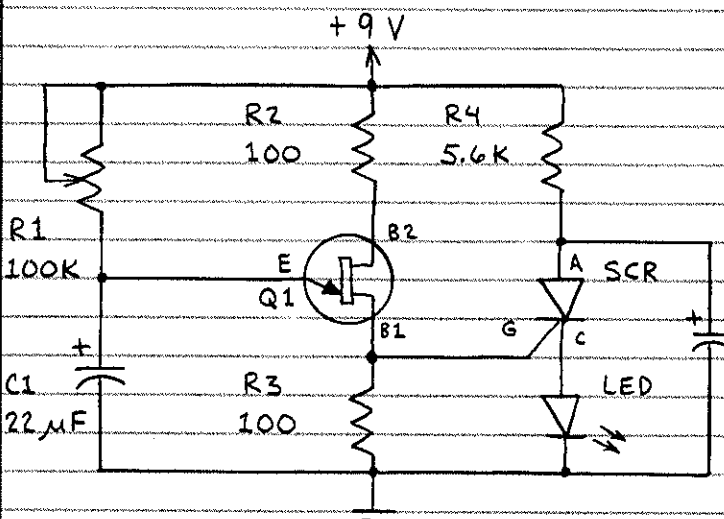
☐ TEST CIRCUIT

S1 IS "SPRING RETURN TO CENTER OFF" SWITCH.



S1 IS AN SPDT SWITCH. IN THE "ON" POSITION, THE SCR IS TURNED ON AND THE LAMP GLOWS. IN THE "OFF" POSITION, CURRENT IS SHUNTED AWAY FROM SCR, THUS TURNING IT OFF.

☐ CAPACITOR DISCHARGE LED FLASHER



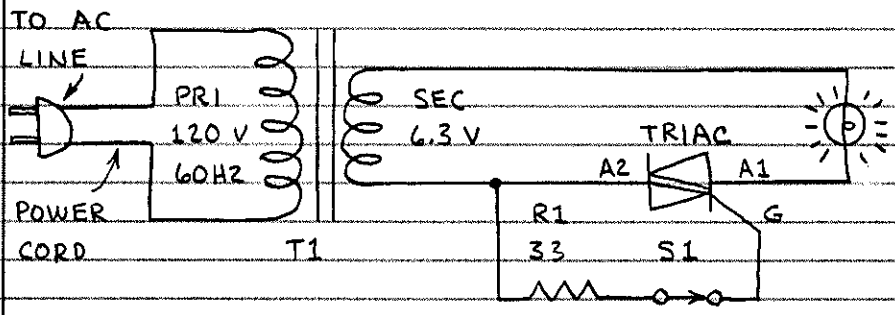
Q1: 2N4891 UJT

R1 CONTROLS RATE.

WHEN THE SCR IS OFF, C2 CHARGES THROUGH R4. WHEN THE SCR IS TURNED ON BY A PULSE FROM UJT Q1, THE CHARGE IN C1 IS RAPIDLY "DUMPED" THROUGH THE LED. THE SCR (AND LED) THEN TURNS OFF SINCE THERE IS NO LONGER SUFFICIENT HOLDING CURRENT. THE CYCLE THEN REPEATS.

TRIAC CIRCUITS

☐ TEST CIRCUIT

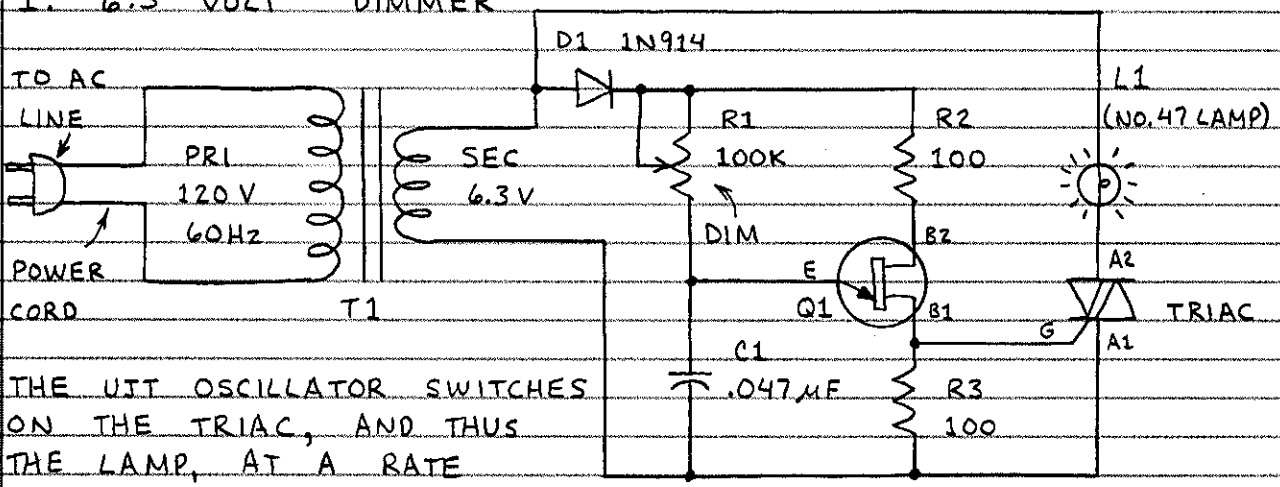


L1 GLOWS WHEN S1 IS CLOSED. L1 DOES NOT GLOW WHEN S1 IS OPEN.

CAUTION:
TRIACS ARE DESIGNED SPECIFICALLY FOR AC OPERATION. BE SURE TO OBSERVE COMMON SENSE SAFETY WHEN WORKING WITH HOUSEHOLD LINE CURRENT! MAKE SURE ALL CONNECTIONS TO AC LINE ARE INSULATED OR ENCLOSED.

☐ LIGHT DIMMER CIRCUITS

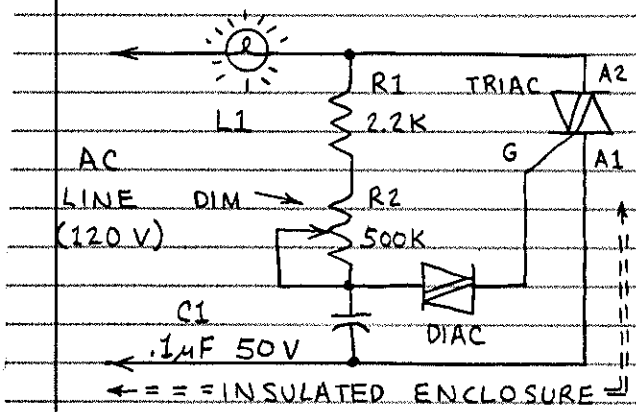
1. 6.3 VOLT DIMMER



THE UJT OSCILLATOR SWITCHES ON THE TRIAC, AND THUS THE LAMP, AT A RATE CONTROLLED BY R1.

Q1: 2N4891 OR SIMILAR UJT.

2. 120 VOLT DIMMER



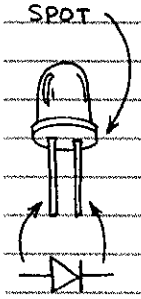
THIS IS HOW MANY HOUSEHOLD DIMMER SWITCHES ARE MADE. L1 CAN BE UP TO 100 WATT (120 VOLT) LAMP. USE HEAT SINK ON TRIAC IF IT BECOMES HOT. THE DIAC IS A BIDIRECTIONAL TRIGGER DIODE.
CAUTION: THIS CIRCUIT MUST BE FULLY ENCLOSED AT ALL TIMES WHEN POWER IS APPLIED!

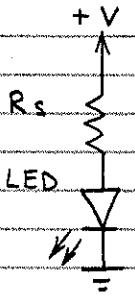
PHOTONIC CIRCUITS

CIRCUITS USING PHOTONIC COMPONENTS ARE AMONG THE MOST VERSATILE AND INTERESTING OF ALL CIRCUITS.

LIGHT EMITTING DIODE (LED) CIRCUITS

☐ LED DRIVE CIRCUIT



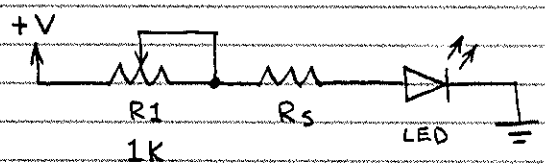


A SERIES RESISTOR MUST BE USED TO LIMIT CURRENT THROUGH AN LED. (EXCEPTIONS: CERTAIN PULSE CIRCUITS AND IC LED DRIVERS.)

$$R_S = \frac{+V - (V_{LED})}{I_{LED}}$$

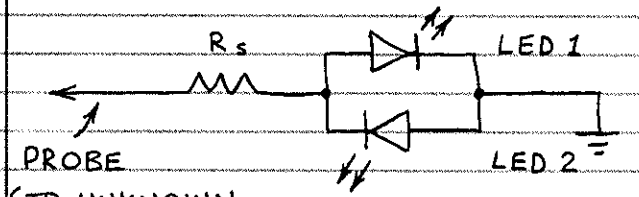
EXAMPLE: ASSUME YOU WANT TO OPERATE A RED LED AT A FORWARD CURRENT (I_{LED}) OF 10 MA (OR 0.01 AMPERE) FROM A 5 VOLT SUPPLY. THE DATA SHEET FOR THE LED LISTS AN LED VOLTAGE (V_{LED}) OF 1.7 VOLTS. THEREFORE R_S IS (5-1.7)/.01 OR 330 OHMS.

☐ VARIABLE BRIGHTNESS LED



ADJUST R1 TO ALTER CURRENT THROUGH THE LED, THUS VARYING ITS BRIGHTNESS. R_S MUST BE USED (SEE ABOVE).

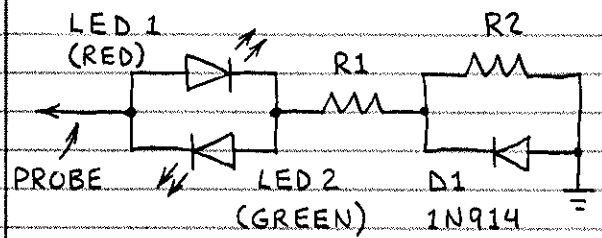
☐ POLARITY INDICATOR



THIS CIRCUIT INDICATES THE POLARITY OF A VOLTAGE. R_S MUST BE USED (SEE ABOVE).

LED	+	−	AC (±)
1	ON	OFF	ON
2	OFF	ON	ON

☐ TRI-STATE POLARITY INDICATOR



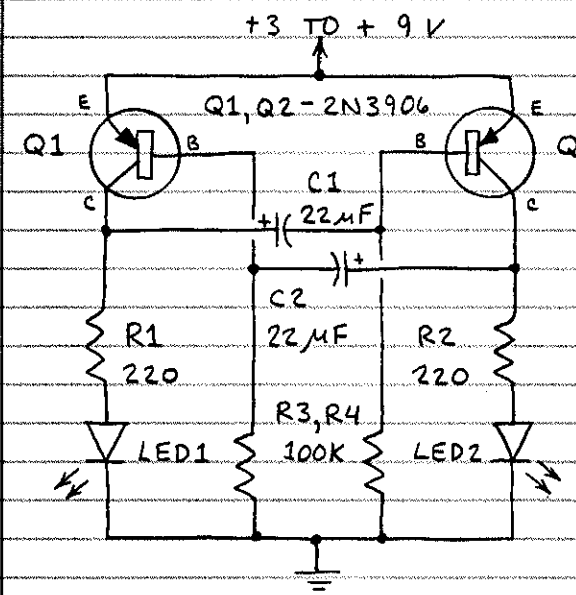
THIS IS A MORE COLORFUL VERSION OF THE CIRCUIT ABOVE.

V_{IN}	COLOR
+	RED
−	GREEN
AC (±)	YELLOW*

$$R1 = \frac{V_{IN} - (V_{LED2} + 0.6)}{I_{LED2}} \qquad R1 + R2 = \frac{V_{IN} - V_{LED1}}{I_{LED1}}$$

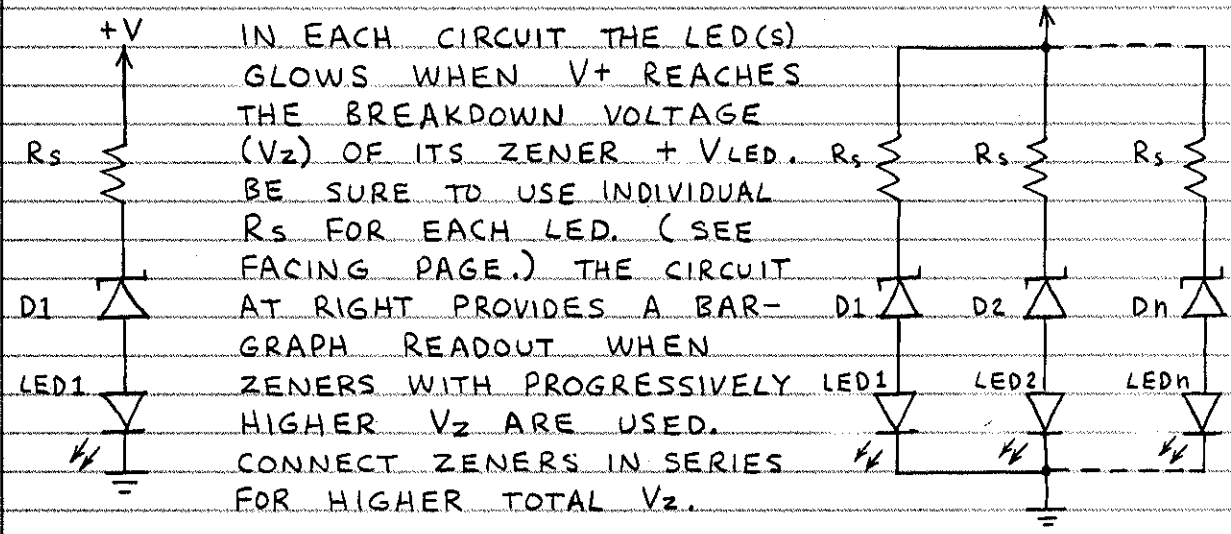
* WHEN TWO-CHIP LED USED.

☐ DUAL LED FLASHER



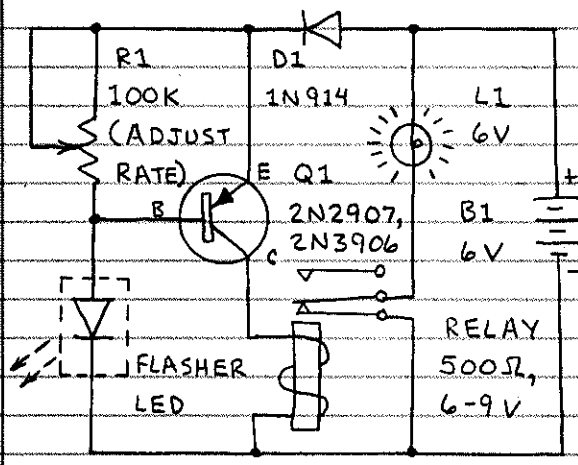
THIS CIRCUIT IS CALLED A FREE-RUNNING MULTIVIBRATOR. IT'S IDENTICAL TO A FLIP-FLOP THAT TRIGGERS ITSELF REPEATEDLY. Q1 AND Q2 ARE GENERAL PURPOSE PNP TRANSISTORS (2N3906, 2N2907, ETC.). R1 AND R2 LIMIT THE CURRENT TO THE LEDs (WHICH FLASH ALTERNATELY). INCREASING THE VALUES OF C1 AND C2 WILL SLOW THE FLASH RATE.

☐ VOLTAGE LEVEL INDICATOR



IN EACH CIRCUIT THE LED(s) GLOWS WHEN V+ REACHES THE BREAKDOWN VOLTAGE (V_Z) OF ITS ZENER + V_{LED}. BE SURE TO USE INDIVIDUAL R_S FOR EACH LED. (SEE FACING PAGE.) THE CIRCUIT AT RIGHT PROVIDES A BAR-GRAPH READOUT WHEN ZENERS WITH PROGRESSIVELY HIGHER V_Z ARE USED. CONNECT ZENERS IN SERIES FOR HIGHER TOTAL V_Z.

☐ FLASHER LED + RELAY

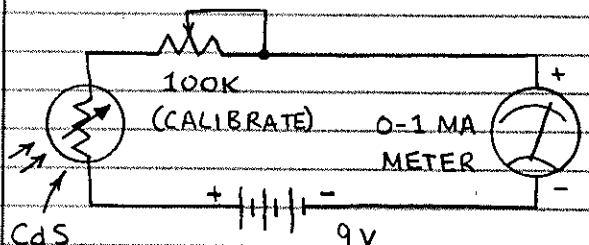


THE FLASHER LED INCLUDES A BUILT-IN IC THAT FLASHES THE LED SEVERAL TIMES EACH SECOND. THIS CIRCUIT SHOWS HOW TO "TAP" THIS FLASH RATE (VIA Q1) TO FORM AN ULTRA-SIMPLE PULSE GENERATOR THAT ACTUATES A RELAY AND, IN TURN, A LAMP. D1 IS NEEDED TO KEEP THE VOLTAGE TO THE FLASHER LED NEAR 5 VOLTS.

SEMICONDUCTOR LIGHT DETECTOR CIRCUITS

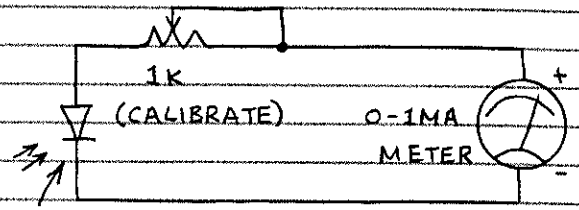
☐ LIGHT METER CIRCUITS

1. PHOTORESISTOR



CdS PHOTORESISTOR

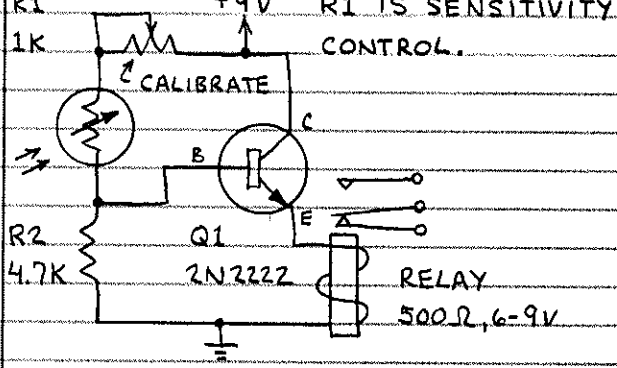
2. SOLAR CELL



SOLAR CELL (OR PHOTODIODE OR PHOTOTRANSISTOR COLLECTOR - BASE)

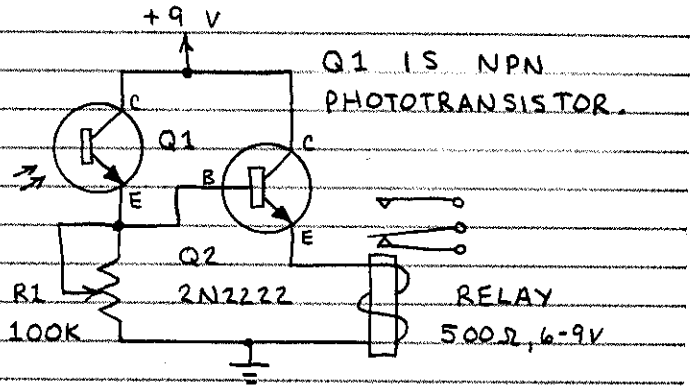
☐ LIGHT ACTUATED RELAY CIRCUITS

1. PHOTORESISTOR



RELAY REMAINS ACTUATED FOR BRIEF TIME AFTER LIGHT REMOVED.

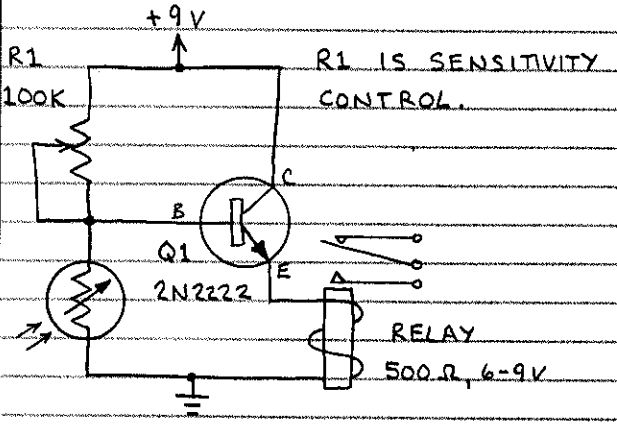
2. PHOTOTRANSISTOR



RESPONDS FASTER THAN PHOTO-RESISTOR CIRCUIT. NO DELAY WHEN LIGHT IS REMOVED.

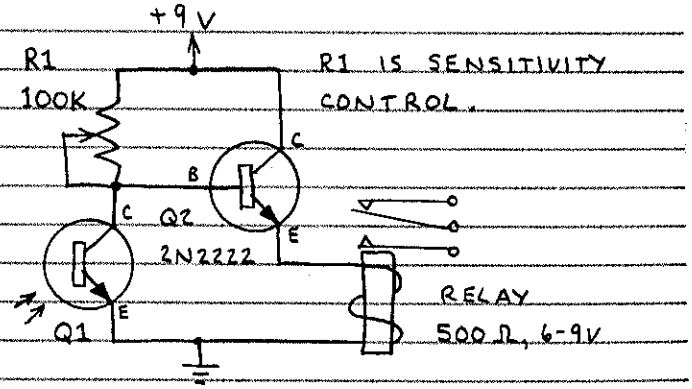
☐ LIGHT DEACTUATED RELAY CIRCUITS

1. PHOTORESISTOR



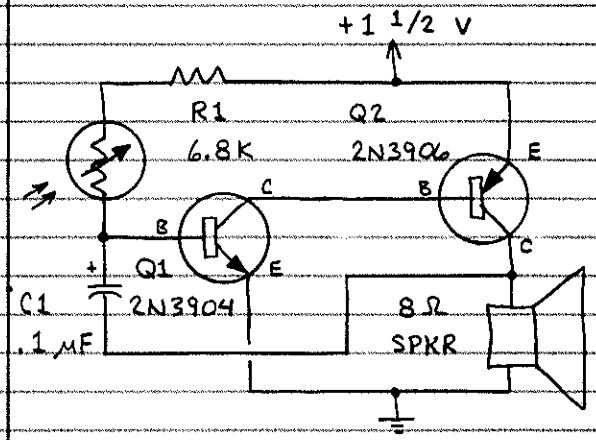
RELAY IS ACTUATED ONLY WHEN THE PHOTORESISTOR IS DARK.

2. PHOTOTRANSISTOR



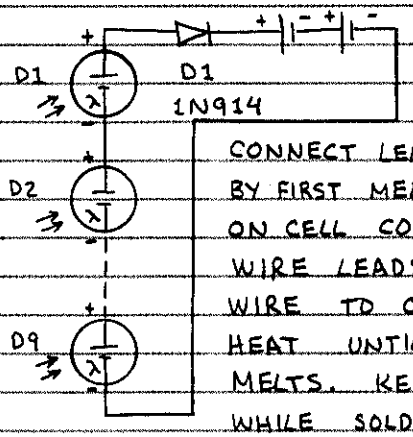
RELAY IS ACTUATED WHEN Q1 IS DARK. LIGHT ON Q1 DEACTUATES RELAY. CALIBRATE WITH R1.

☐ AUDIBLE LIGHT PROBE



THIS IS AMONG THE MOST ENTERTAINING CIRCUITS IN THIS BOOK. VARIOUS PNP AND NPN TRANSISTORS CAN BE USED FOR Q1 AND Q2. THE TONE FROM THE SPEAKER INCREASES IN FREQUENCY AS THE INTENSITY OF LIGHT ON THE PHOTORESISTOR INCREASES. VERY SENSITIVE! TRY THIS: OPERATE CIRCUIT IN A DARK ROOM UNTIL TONE SLOWS TO A SERIES OF CLICKS. THEN SHINE BEAM FROM FLASHLIGHT ON THE PHOTORESISTOR...

☐ SOLAR CELL BATTERY CHARGER

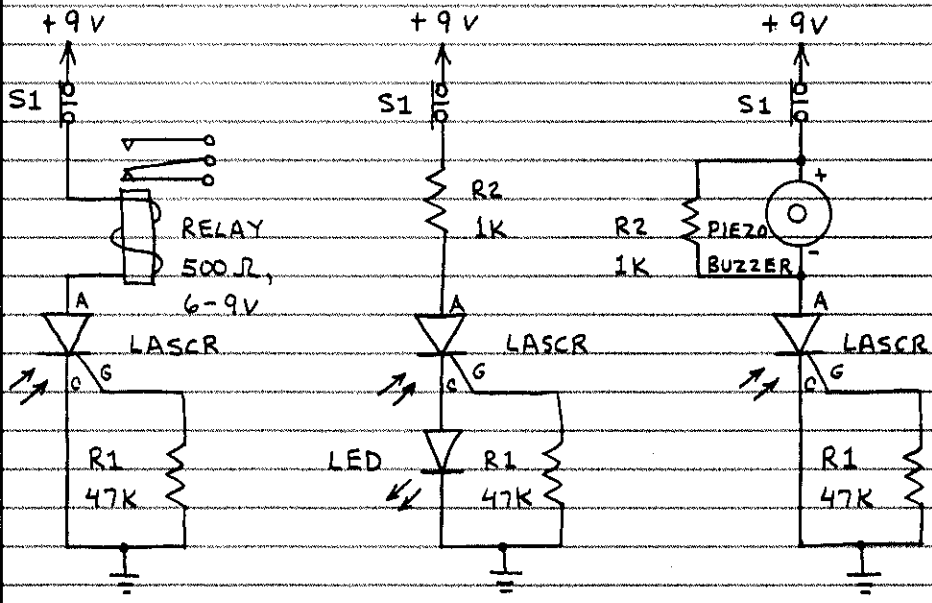


CONNECT LEADS TO CELLS BY FIRST MELTING SOLDER ON CELL CONTACTS AND WIRE LEADS. TOUCH WIRE TO CONTACT AND HEAT UNTIL SOLDER MELTS. KEEP LEAD STILL WHILE SOLDER HARDENS.

USE NINE CELLS TO CHARGE TWO NICADS. CURRENT FROM SOLAR CELLS MUST NOT EXCEED MAXIMUM CHARGING RATE FOR NICADS! YOU CAN MONITOR CURRENT BY CONNECTING MULTIMETER BETWEEN NICADS AND D1. INSERT SERIES RESISTOR OR REMOVE SOLAR CELL TO REDUCE CURRENT. D1 KEEPS NICADS FROM DISCHARGING THROUGH SOLAR CELLS (WHEN DARK). SOLAR CELLS ARE FRAGILE. SOLDER AND MOUNT WITH CARE.

☐ LIGHT ACTUATED LATCHING CIRCUITS

1. RELAY 2. LED (OR LAMP) 3. BUZZER



C A G

THESE CIRCUITS ARE ACTUATED BY LASCR LIGHT. OPEN (MAY S1 TO SWITCH VARY) LASCR OFF. SOME LASCRS ARE MORE LIGHT SENSITIVE THAN OTHERS. MOST WILL TRIGGER IN RESPONSE TO LIGHT FROM CAMERA STROBE (XENON FLASH UNIT).

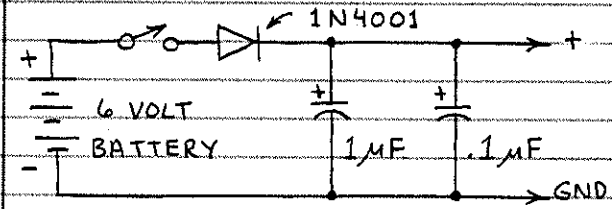
DIGITAL IC CIRCUITS

DIGITAL ICs ARE VERY EASY TO USE. HERE'S A SELECTION OF TTL AND CMOS CIRCUITS:

TTL CIRCUITS

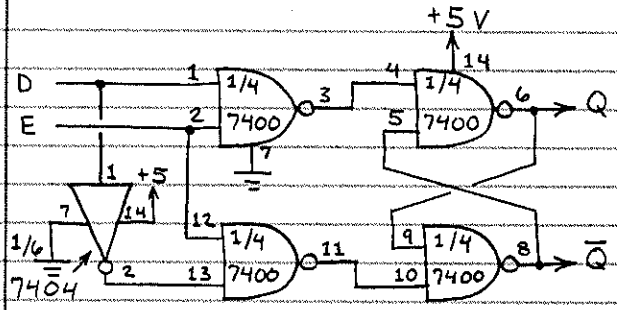
☐ OPERATING REQUIREMENTS

1. POWER SUPPLY MUST NOT EXCEED 5.25 VOLTS. SEE PAGE 125 OR USE:



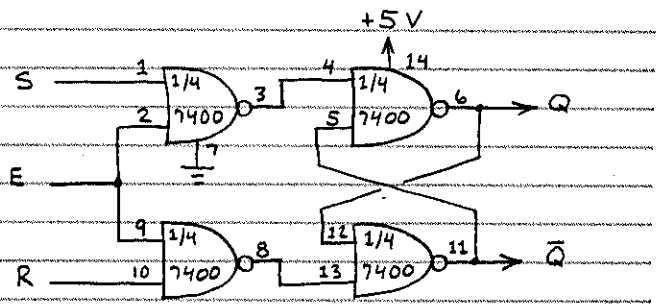
2. INPUTS MUST NOT EXCEED +5.25 V.
3. INPUTS SHOULD ALWAYS GO SOMEWHERE (NOT LEFT "FLOATING").
4. FORCE OUTPUTS OF UNUSED GATES "H" TO SAVE POWER. (EXAMPLE: UNUSED "NAND" – MAKE ONE INPUT H.)
5. AVOID LONG WIRES IN CIRCUITS.
6. CONNECT 1 TO 10 μF CAPACITOR ACROSS POWER LEADS WHERE THEY ENTER CIRCUIT.
7. CONNECT 0.1 μF CAPACITOR ACROSS POWER PINS OF EACH TTL CHIP IN MULTI-CHIP CIRCUITS.
8. REMEMBER, TTL USES MUCH MORE CURRENT THAN LS OR CMOS.

☐ "D" FLIP-FLOP



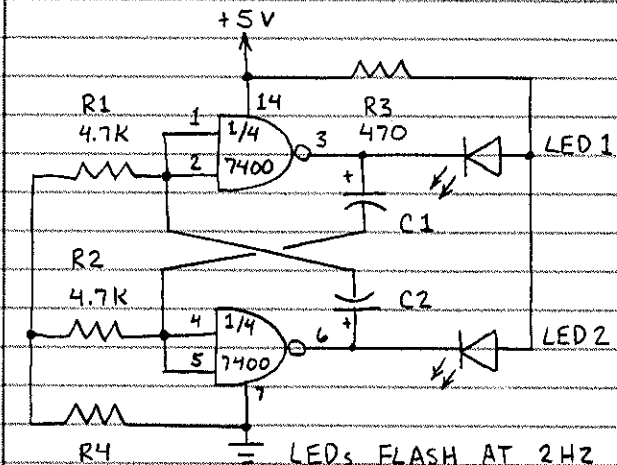
Q = D WHEN ENABLE (E) IS HIGH. NO CHANGE WHEN E IS LOW.

☐ CLOCKED "RS" FLIP-FLOP



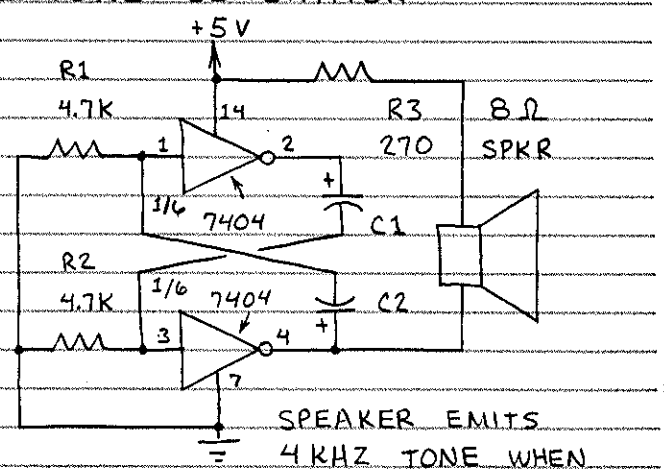
FUNCTIONS AS "RS" FLIP-FLOP WHEN ENABLE (E) IS HIGH.

☐ DUAL LED FLASHER



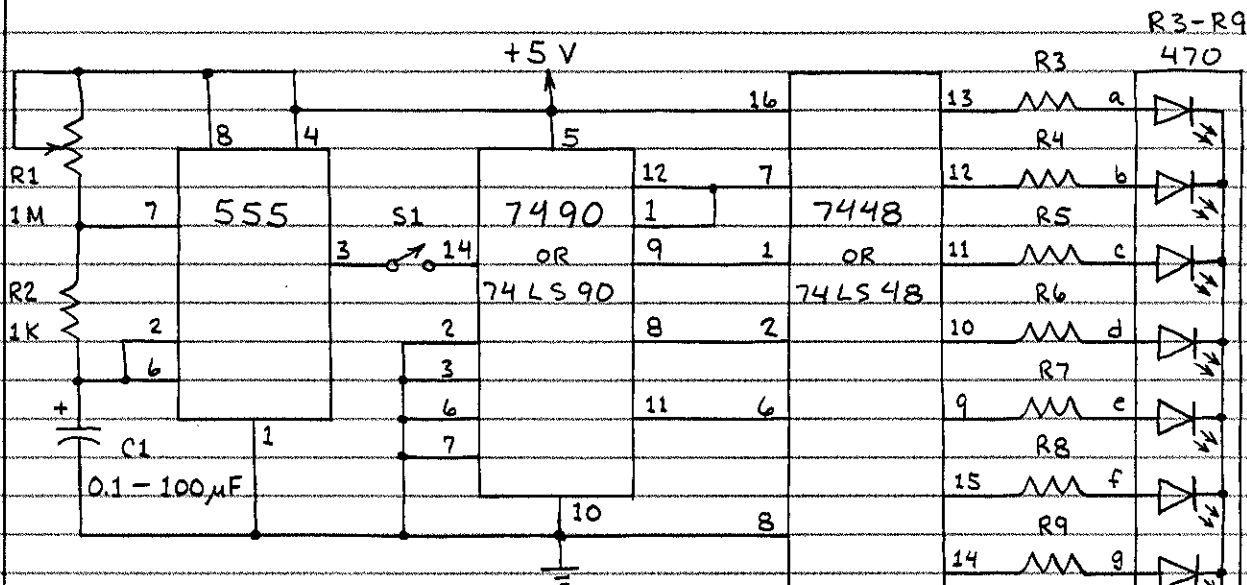
LEDs FLASH AT 2 HZ WHEN C1 = C2 = 47 μF.

☐ TONE GENERATOR

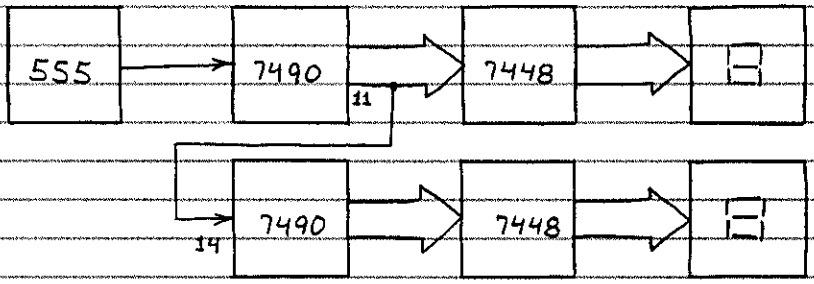


SPEAKER EMITS 4 KHZ TONE WHEN C1 = C2 = 0.1 μF.

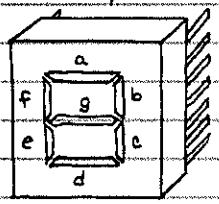
☐ 0 TO 9 SECOND (OR MINUTE) TIMER



CLOSE S1 AND PULSES FROM THE 555 WILL BE COUNTED BY THE 7490. THE 7448 CONVERTS THE BCD OUTPUT FROM THE 7490 INTO 7-SEGMENT DIGITS ON AN LED DISPLAY. ADJUST R1 AND C1 FOR DESIRED PULSE RATE. TO ADD ADDITIONAL DIGIT:

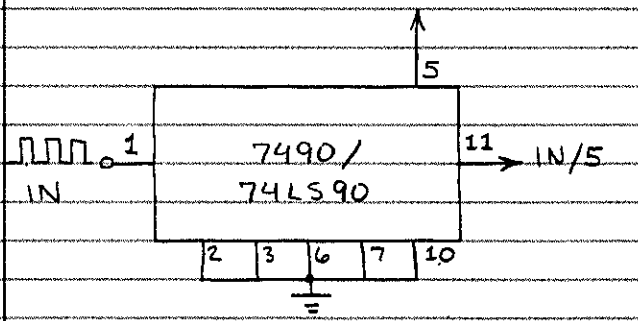


COMMON CATHODE 7-SEGMENT DISPLAY



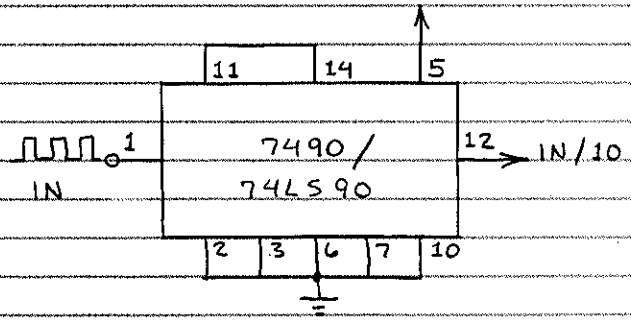
HINT:
THIS BASIC CIRCUIT WILL COUNT PULSES FROM OTHER CIRCUITS. ELIMINATE 555 AND APPLY PULSES (5 VOLTS MAXIMUM) TO 7490.

☐ DIVIDE-BY-5 COUNTER



DIVIDES INCOMING "TRAIN" OF PULSES BY 5. OK TO USE AT INPUT OF CIRCUIT ABOVE.

☐ DIVIDE-BY-10 COUNTER

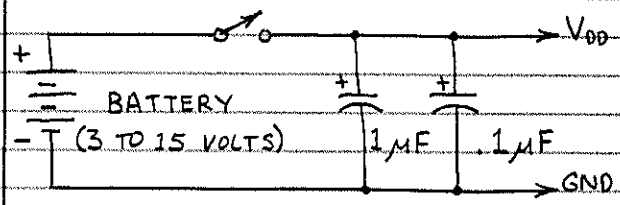


DIVIDES INCOMING "TRAIN" OF PULSES BY 10. OK TO USE AT INPUT OF CIRCUIT ABOVE.

CMOS CIRCUITS

☐ OPERATING REQUIREMENTS

1. THE POSITIVE POWER TO A CMOS CHIP (V_{DD}) CAN RANGE FROM +3 TO +15 (OR +18) VOLTS. USE POWER SUPPLIES ON PAGE 125 OR A BATTERY (BEST):

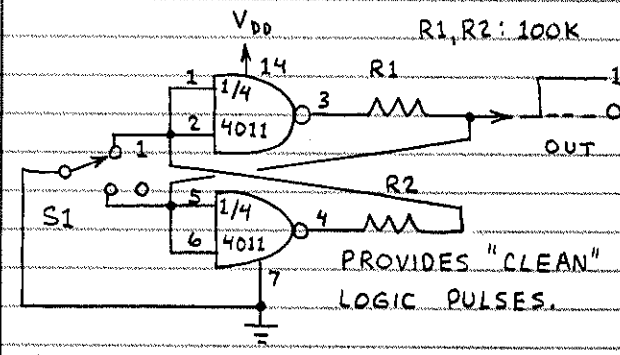


2. INPUTS MUST NOT EXCEED V_{DD}.
3. ALL UNUSED INPUTS MUST GO TO V_{DD} OR GND ($\frac{}{=}$).
4. NEVER APPLY AN INPUT SIGNAL TO AN UNPOWERED CMOS CIRCUIT.

☐ HANDLING PRECAUTIONS

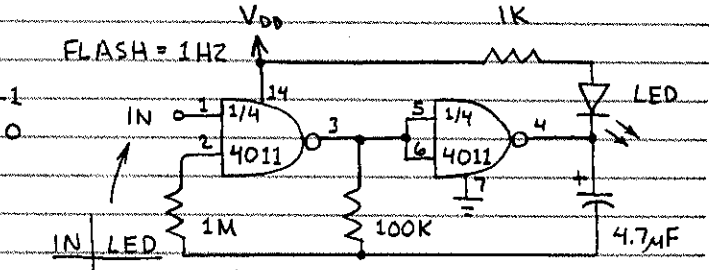
1. PLACE CMOS ICs PINS DOWN ON AN ALUMINUM FOIL SHEET OR TRAY WHEN THEY ARE NOT IN A CIRCUIT OR PROPERLY STORED.
2. NEVER STORE CMOS ICs IN NONCONDUCTIVE PLASTIC "SNOW," TRAYS, BAGS OR FOAM. PLUG THEM IN CONDUCTIVE FOAM OR FOAMED PLASTIC WRAPPED IN ALUMINUM FOIL.
3. AVOID USING AN AC LINE POWERED IRON TO SOLDER PINS OF CMOS ICs. USE IC SOCKETS, WIRE-WRAP OR BATTERY POWERED IRON.
4. DRAIN STATIC CHARGE ON YOUR BODY BY TOUCHING GROUNDED OBJECT.

☐ BOUNCELESS SWITCH



PROVIDES "CLEAN" LOGIC PULSES.

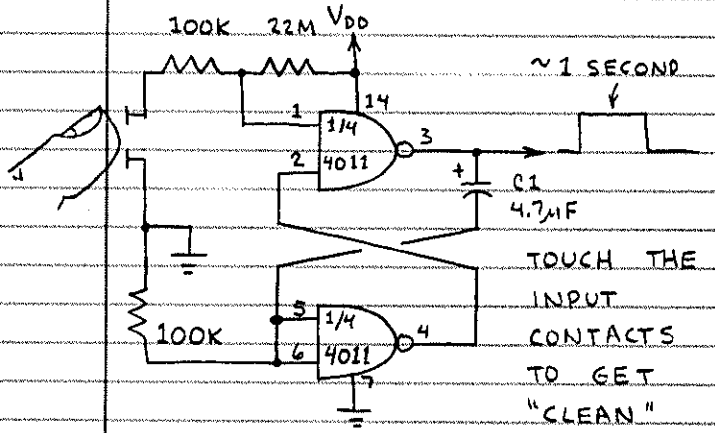
☐ SINGLE LED "GATED" FLASHER



IN	LED
L	ON
H	FLASH

(ADD INVERTER BETWEEN PIN 4 AND LED FOR L = OFF.)

☐ "ONE-SHOT" TOUCH SWITCH

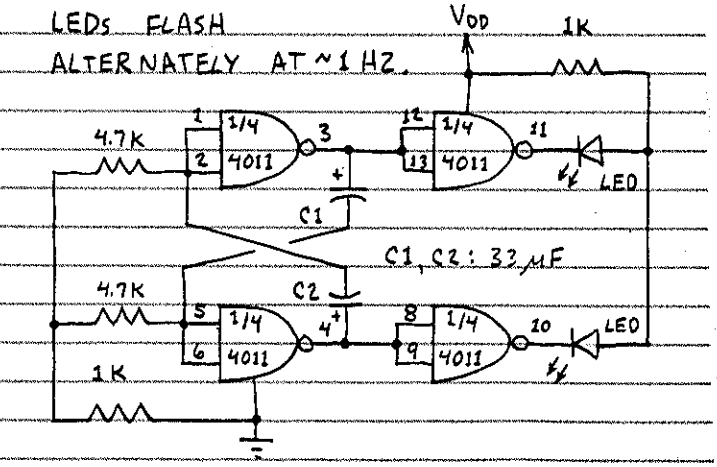


TOUCH THE INPUT CONTACTS TO GET "CLEAN" OUTPUT PULSE.

C1 CONTROLS LENGTH OF OUTPUT PULSE.

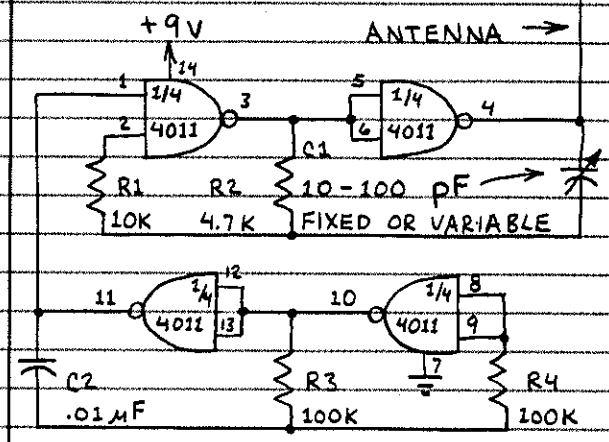
☐ DUAL LED FLASHER

LEDs FLASH ALTERNATELY AT ~1 HZ.



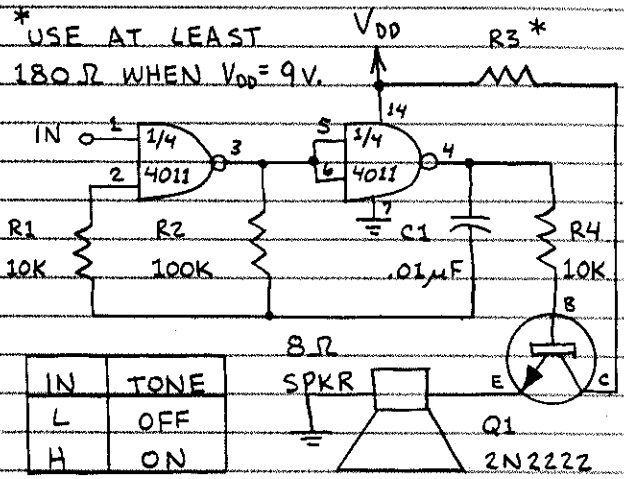
CHANGE C1 AND C2 TO CHANGE RATE.

☐ MINI RADIO TRANSMITTER



SENDS TONE TO NEARBY RADIO. TUNE RADIO AND/OR C1 TO HEAR TONE. USE INSULATED TOOL TO TUNE C1. C2 CONTROLS TONE FREQUENCY. USE 1-2 FEET OF WIRE FOR ANTENNA.

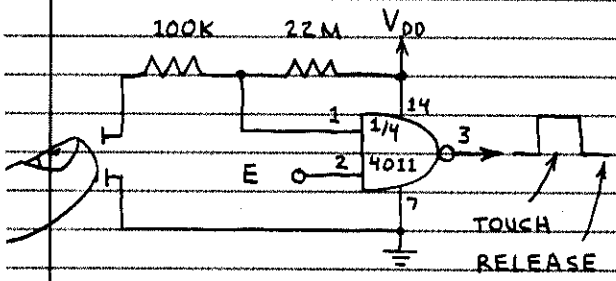
☐ "GATED" TONE GENERATOR



IN	TONE
L	OFF
H	ON

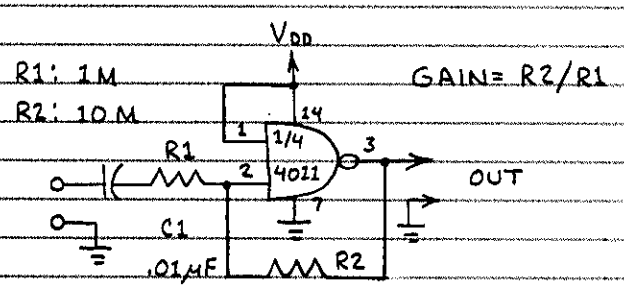
VALUES SHOWN GIVE 1.3 KHZ TONE. C1 AND R2 CONTROL TONE FREQUENCY. R3 CONTROLS VOLUME. INPUT CAN BE SWITCH (V_{DD} / GND) OR LOGIC SIGNAL.

☐ STANDARD TOUCH SWITCH



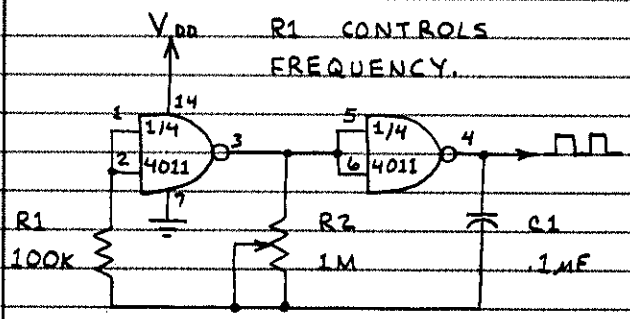
WHEN THE ENABLE INPUT (E) IS HIGH, THE CIRCUIT RESPONDS.

☐ LINEAR ×10 AMPLIFIER



THIS IS A NON-DIGITAL ROLE FOR A DIGITAL GATE.

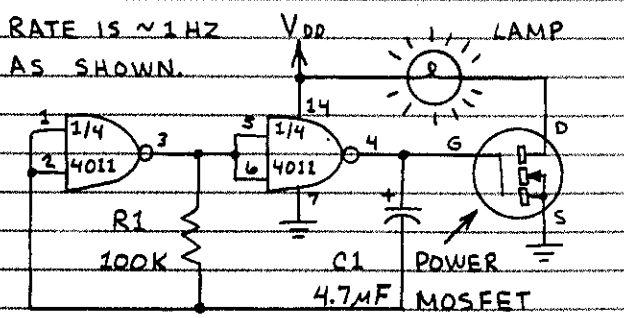
☐ FREQUENCY GENERATOR



R1 CONTROLS FREQUENCY.

USE TO SUPPLY "CLOCK" PULSES TO OTHER CMOS CIRCUITS.

☐ LAMP FLASHER



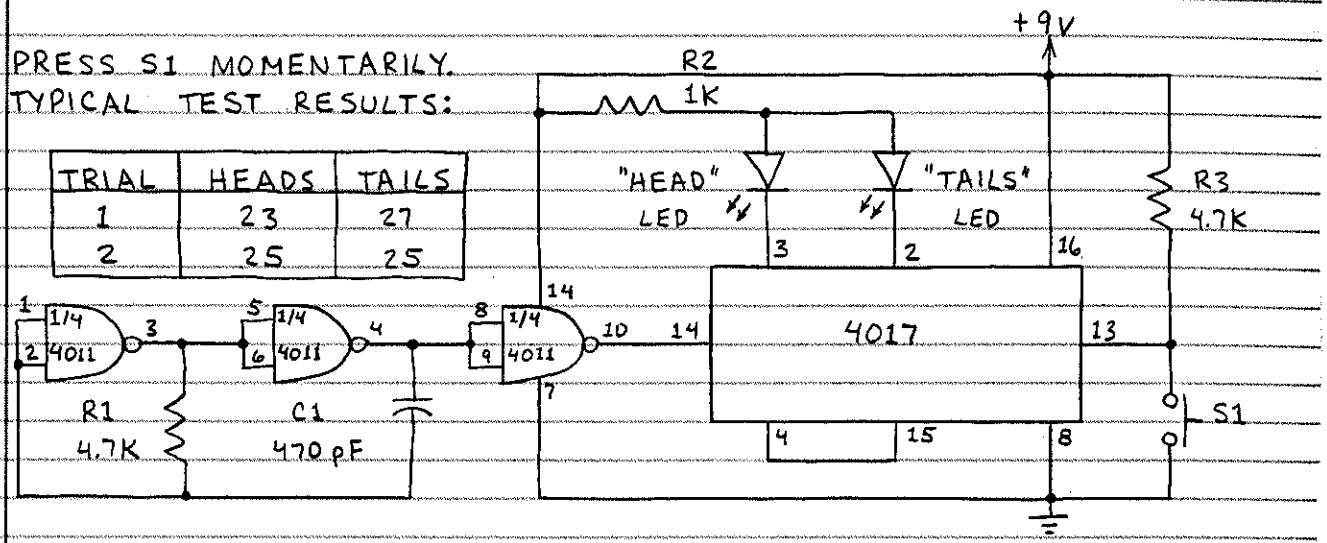
RATE IS ~1 HZ AS SHOWN.

C1 AND R1 CONTROL RATE. OK TO USE SEPARATE SUPPLY FOR LAMP.

☐ ELECTRONIC COIN TOSSER

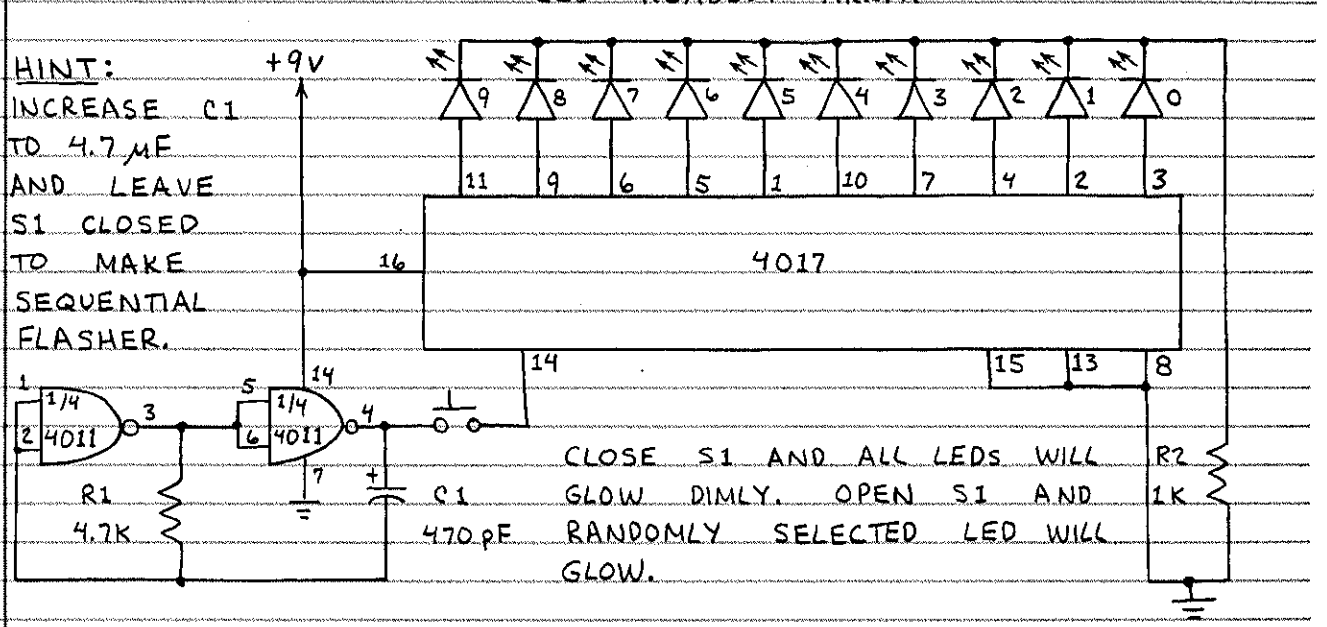
PRESS S1 MOMENTARILY.
TYPICAL TEST RESULTS:

TRIAL	HEADS	TAILS
1	23	27
2	25	25



☐ RANDOM NUMBER GENERATOR

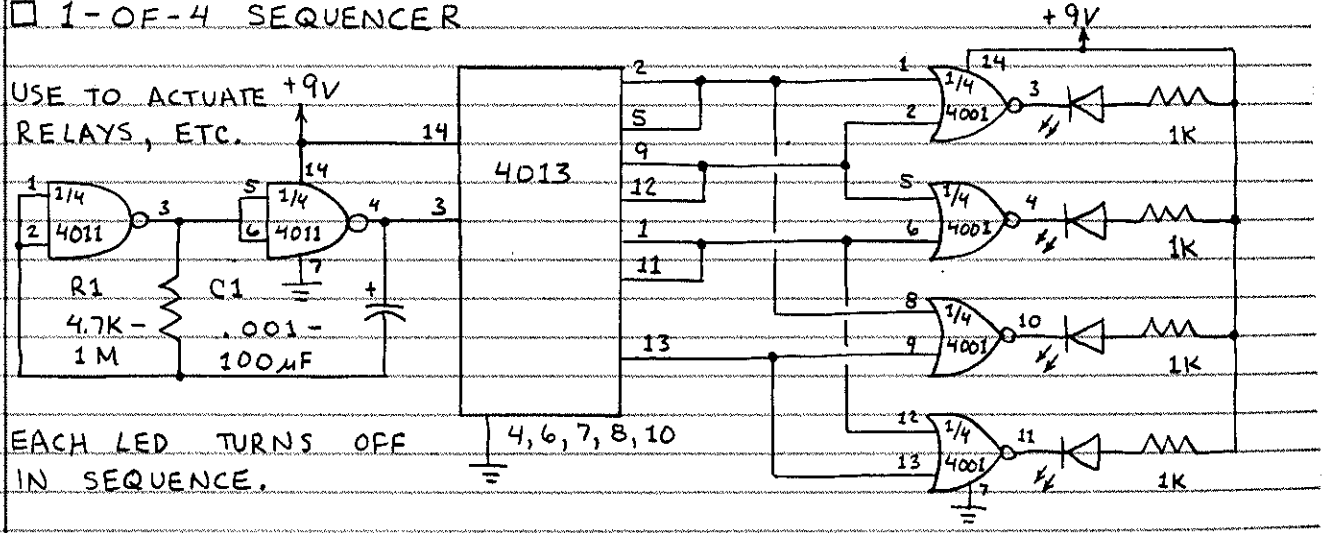
HINT:
INCREASE C1 TO 4.7 μF AND LEAVE S1 CLOSED TO MAKE SEQUENTIAL FLASHER.



CLOSE S1 AND ALL LEDs WILL GLOW DIMLY. OPEN S1 AND RANDOMLY SELECTED LED WILL GLOW.

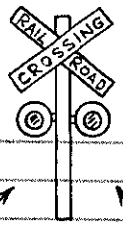
☐ 1-OF-4 SEQUENCER

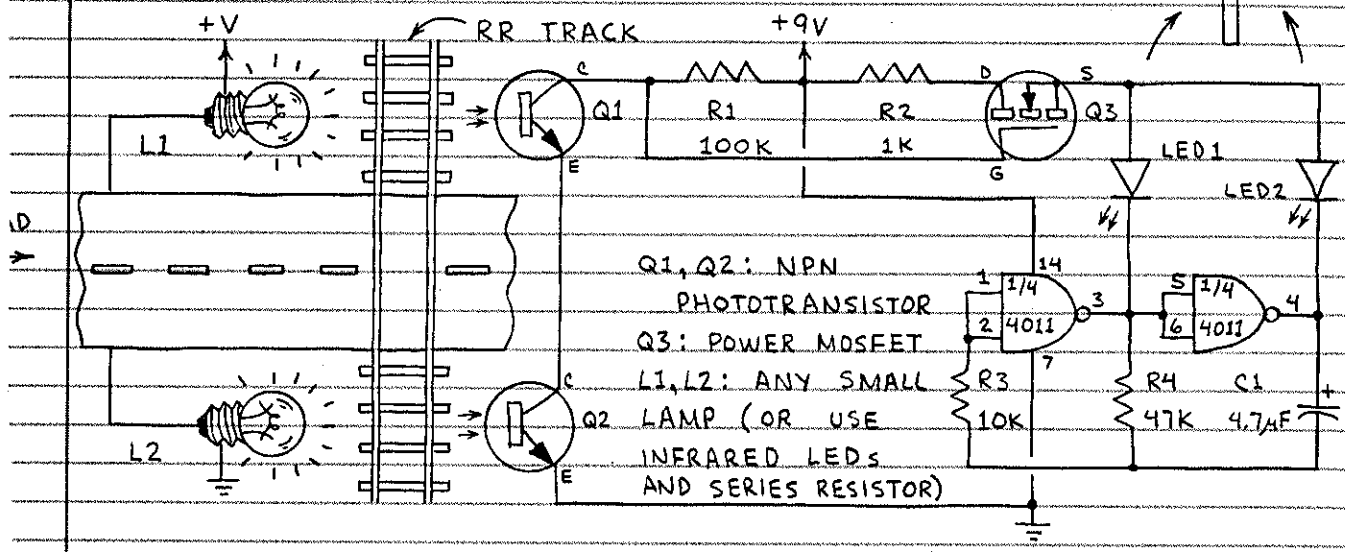
USE TO ACTUATE RELAYS, ETC.



EACH LED TURNS OFF IN SEQUENCE.

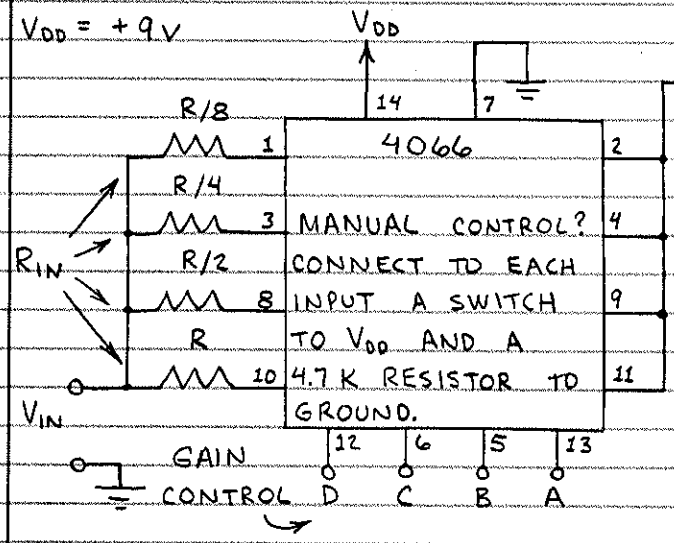
☐ MODEL RAILROAD CROSSING FLASHER LIGHTS

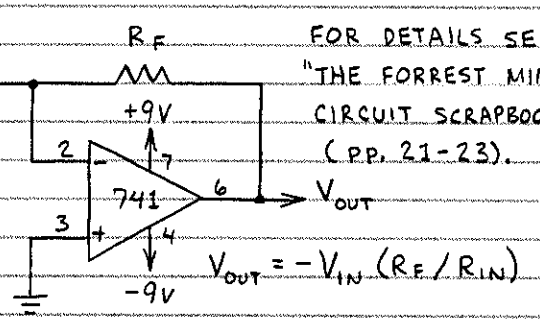




LEDS FLASH ALTERNATELY WHEN TRAIN BREAKS LIGHT BEAM TO EITHER Q1 OR Q2. LEDS CONTINUE FLASHING UNTIL TRAIN PASSES. SHIELD Q1 AND Q2 FROM ROOM LIGHTS WITH 1" HEAT SHRINK TUBING.

☐ PROGRAMMABLE GAIN OPERATIONAL AMPLIFIER

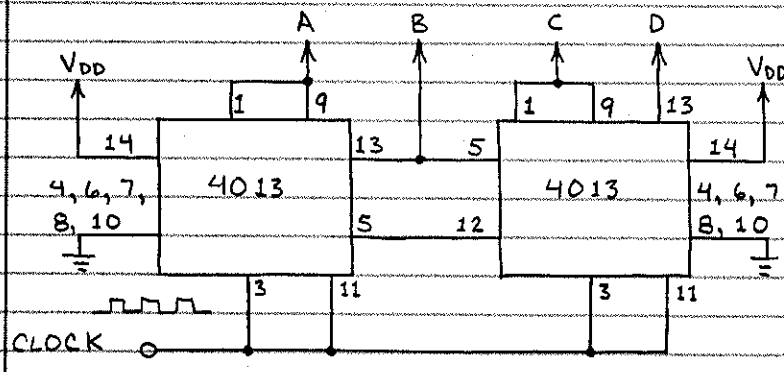




FOR DETAILS SEE "THE FORREST MIMS CIRCUIT SCRAPBOOK" (PP. 21-23).

APPLY CONTROL SIGNALS AT DCBA INPUTS TO ALTER R_{IN}. 0001 TO 1111 VARIES R_{IN} FROM R TO R/15. TYPICAL R, R_F = 10K.

☐ ALL ON — ALL OFF SEQUENCER



ALL OUTPUTS GO LOW, THEN HIGH, IN SEQUENCE (A...B...C...D...A...B... ETC.). USE WITH LEDS FOR EYE-CATCHING DISPLAY. FOR "BUCKET-BRIGADE" OPERATION, CONNECT PIN 5 OF FIRST 4013 TO PIN 13 (NOT 12) OF SECOND 4013.

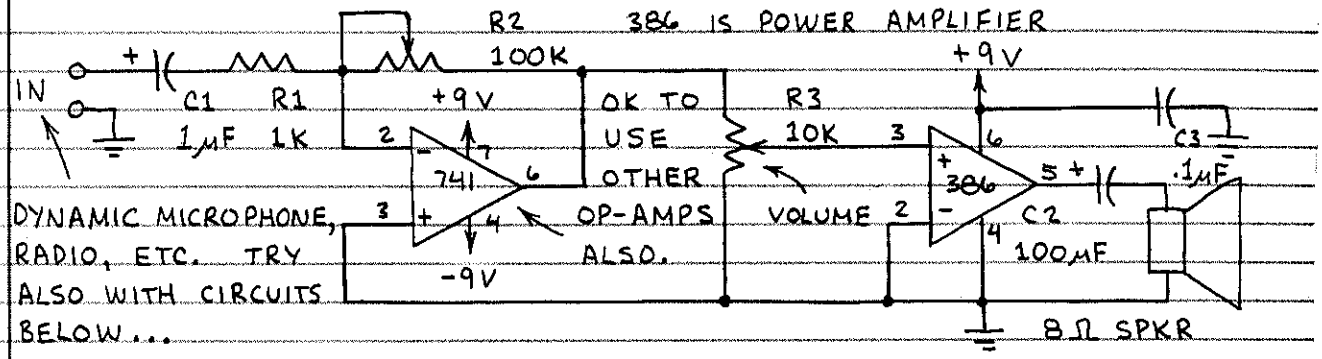
LINEAR IC CIRCUITS

YOU CAN MAKE AN AMAZING VARIETY OF CIRCUITS WITH LINEAR ICs. HERE ARE A FEW OF THE MANY POSSIBILITIES:

OPERATIONAL AMPLIFIER (OP-AMP) CIRCUITS

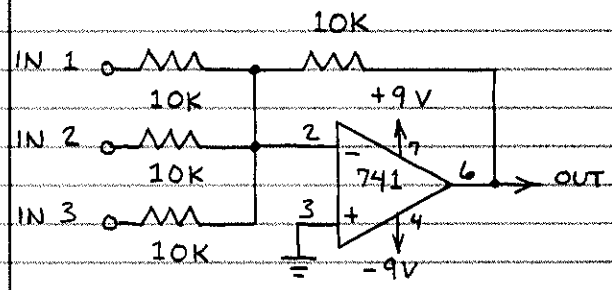
☐ AUDIO AMPLIFIER

741 IS PREAMPLIFIER (R2 SETS GAIN)
386 IS POWER AMPLIFIER



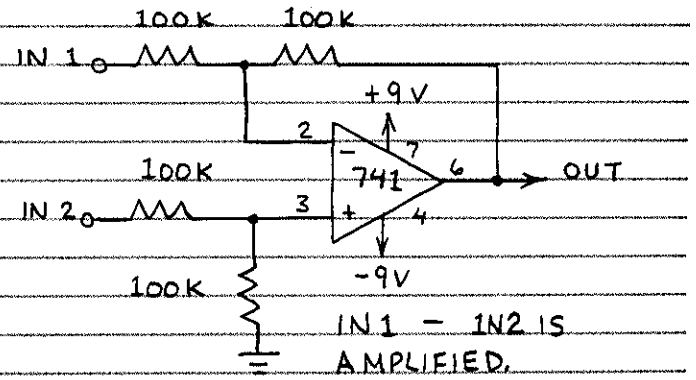
DYNAMIC MICROPHONE, RADIO, ETC. TRY ALSO WITH CIRCUITS BELOW...

☐ MIXER



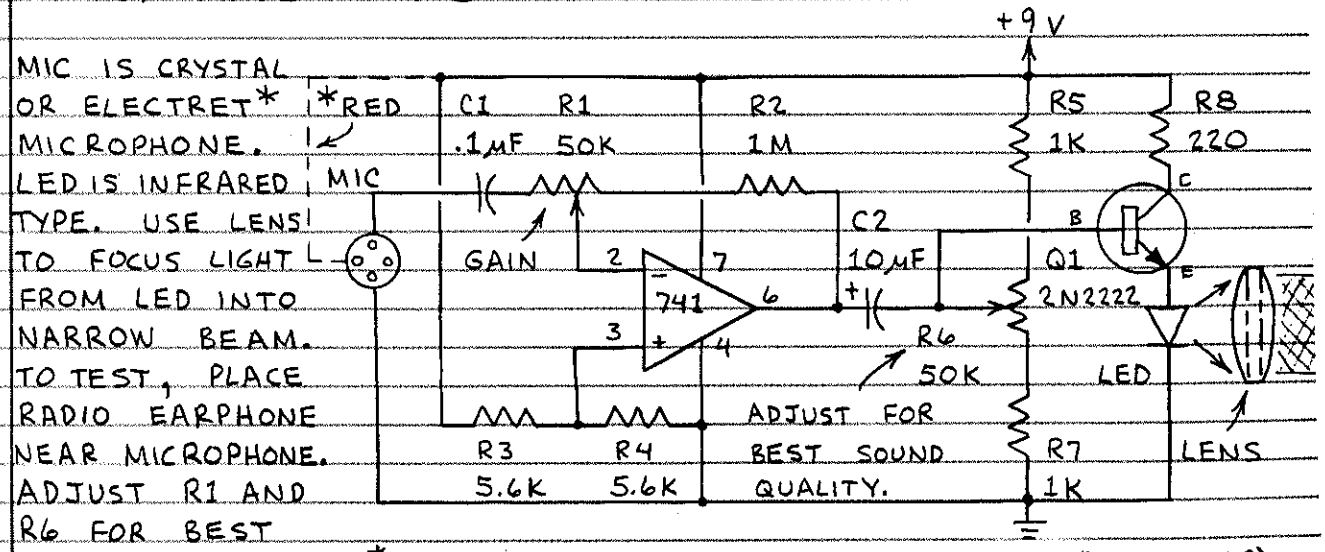
SEVERAL SIMULTANEOUS INPUTS. USE WITH AUDIO AMPLIFIER ABOVE.

☐ DIFFERENCE AMPLIFIER



IN1 − IN2 IS AMPLIFIED.

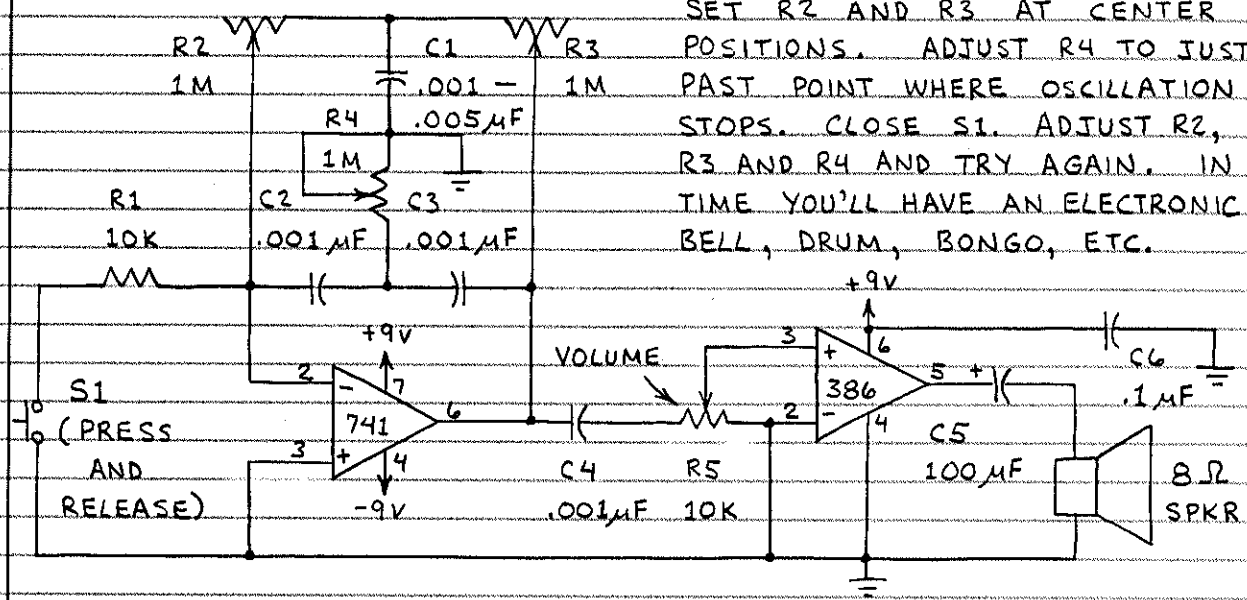
☐ LIGHTWAVE VOICE TRANSMITTER*



MIC IS CRYSTAL OR ELECTRET* MICROPHONE. LED IS INFRARED TYPE. USE LENS TO FOCUS LIGHT FROM LED INTO NARROW BEAM. TO TEST, PLACE RADIO EARPHONE NEAR MICROPHONE. ADJUST R1 AND R6 FOR BEST RECEIVER SOUND.

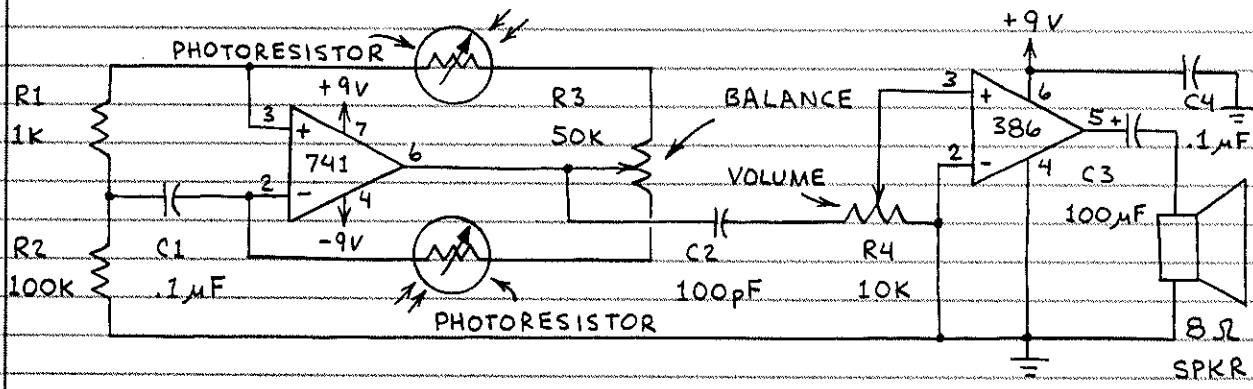
*SEE "THE FORREST MIMS CIRCUIT SCRAPBOOK" (PP. 35-42).

☐ PERCUSSION SYNTHESIZER (BELL, DRUM, ETC.)



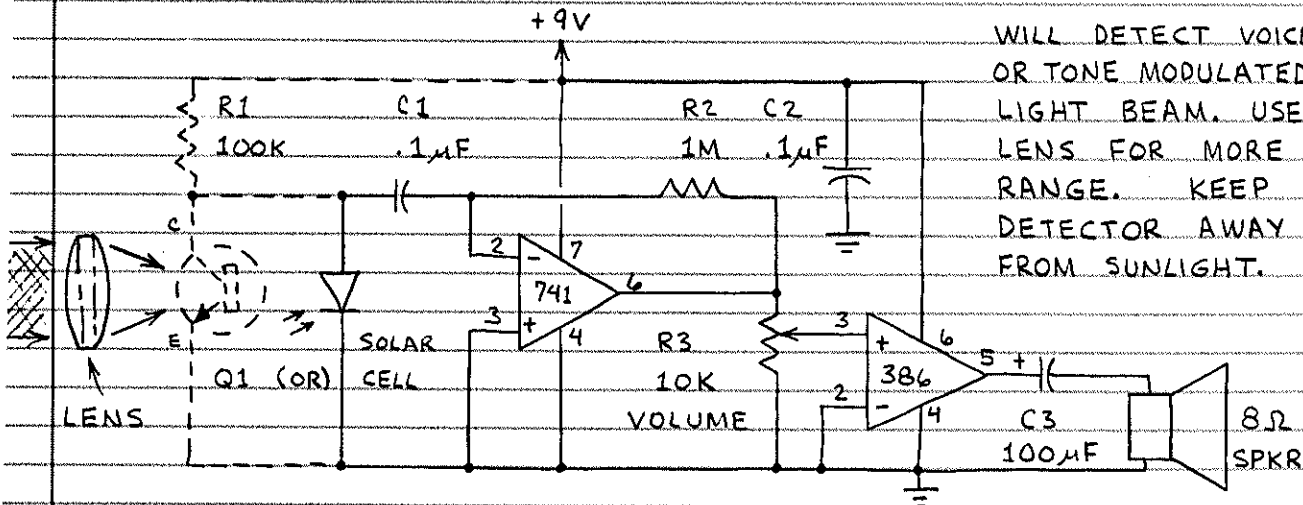
SET R2 AND R3 AT CENTER POSITIONS. ADJUST R4 TO JUST PAST POINT WHERE OSCILLATION STOPS. CLOSE S1. ADJUST R2, R3 AND R4 AND TRY AGAIN. IN TIME YOU'LL HAVE AN ELECTRONIC BELL, DRUM, BONGO, ETC.

☐ LIGHT SENSITIVE UP-DOWN TONE GENERATOR



TAKE THIS CIRCUIT AND A FLASHLIGHT INTO A DARK ROOM...

☐ LIGHTWAVE COMMUNICATIONS RECEIVER

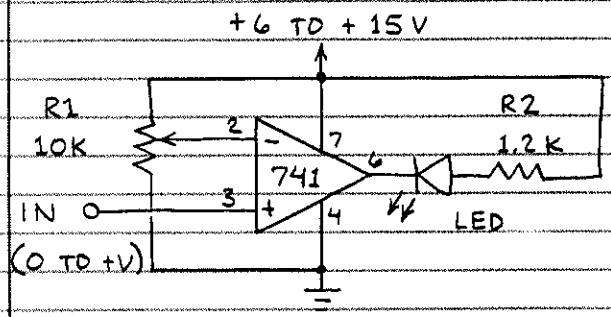


WILL DETECT VOICE OR TONE MODULATED LIGHT BEAM. USE LENS FOR MORE RANGE. KEEP DETECTOR AWAY FROM SUNLIGHT.

DETECTOR: USE R1 AND Q1 OR SOLAR CELL. (Q1: PHOTOTRANSISTOR)

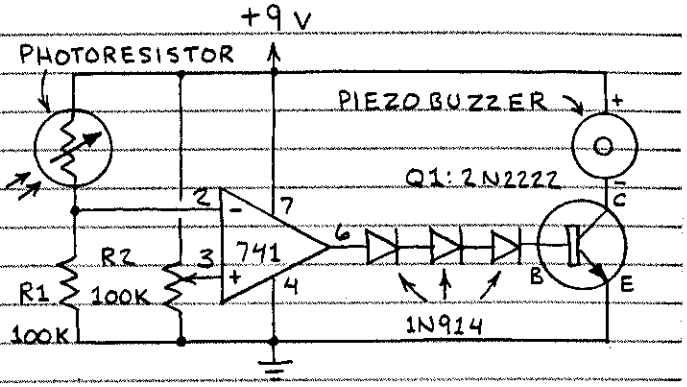
COMPARATOR CIRCUITS

☐ VOLTAGE MONITOR



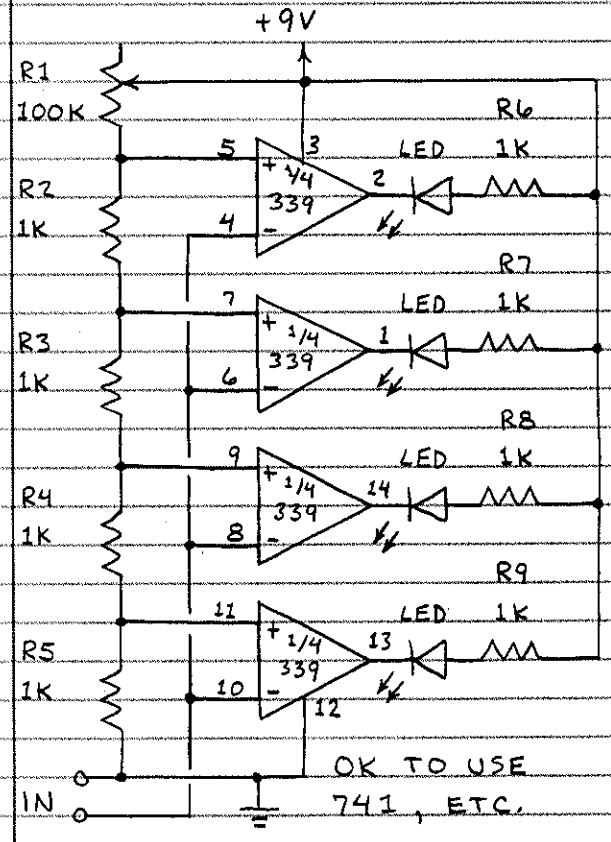
WHEN THE INPUT VOLTAGE IS 0, THE LED GLOWS. THE LED SWITCHES OFF WHEN THE INPUT VOLTAGE RISES TO A LEVEL DETERMINED BY R1. EXCHANGE CONNECTIONS TO PINS 2 AND 3 TO REVERSE OPERATING MODE.

☐ LIGHT LEVEL INDICATOR



BUZZER SOUNDS WHEN LIGHT FALLS TO LEVEL DETERMINED BY R2. REVERSE CONNECTIONS TO PINS 2 AND 3 TO SOUND TONE WHEN LIGHT INCREASES.

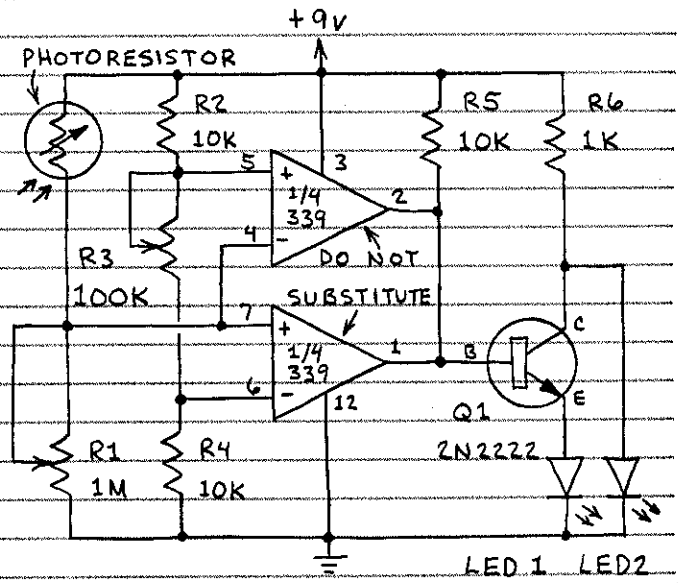
☐ BARGRAPH VOLTAGE INDICATOR



OK TO USE 741, ETC.

LEDs GLOW IN SEQUENCE AS INPUT VOLTAGE RISES. R1 CONTROLS SENSITIVITY.

☐ "WINDOW" COMPARATOR



SET R1 TO CENTER POSITION. TURN OFF LIGHTS AND ROTATE R3 JUST PAST POINT WHERE LED 2 GLOWS. CIRCUIT WILL THEN RESPOND LIKE THIS: (R1 & R3 CONTROL RESPONSE)

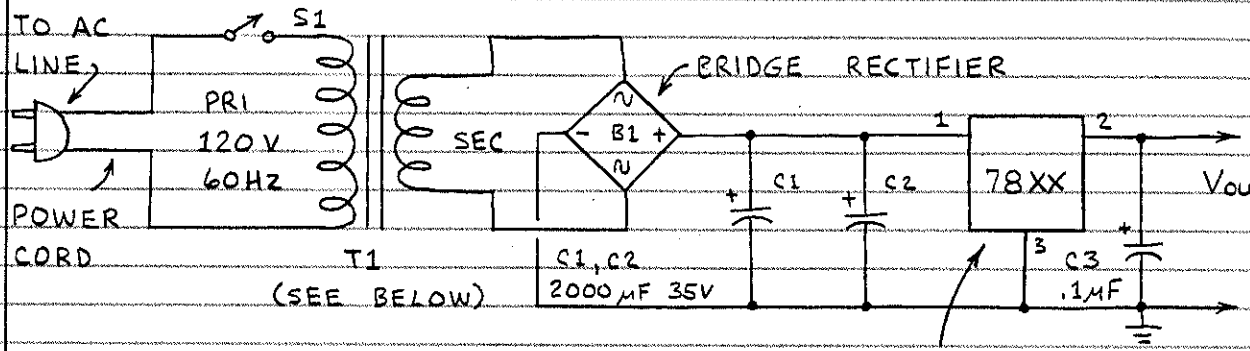
DARK ⟶ LIGHT

LED 1 = OFF ⟵ ON ⟶ OFF

LED 2 = ON ⟵ OFF ⟶ ON

VOLTAGE REGULATOR CIRCUITS

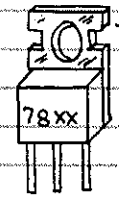
☐ FIXED OUTPUT LINE POWERED SUPPLY



THIS BASIC SUPPLY WILL DELIVER UP TO 1.5 AMPERES AT THE RATED OUTPUT IF PROPERLY HEAT SUNK. YOU MUST USE A TRANSFORMER RATED AT THE PROPER VOLTAGE AND CURRENT. THE REGULATOR WILL "SHUT DOWN" IF THE CHIP BECOMES OVERHEATED. FOR BEST RESULTS APPLY SILICONE COMPOUND BETWEEN TAB AND HEAT SINK. ALL CONNECTIONS TO THE AC LINE MUST BE INSULATED OR ENCLOSED!

REGULATOR IC

7805 = 5 VOLTS
7812 = 12 VOLTS
7815 = 15 VOLTS

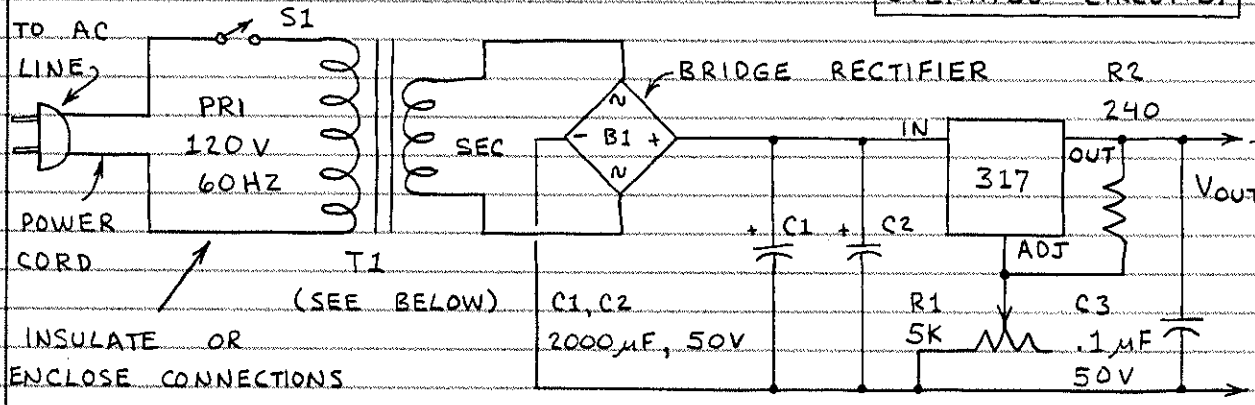


HEAT SINK TAB

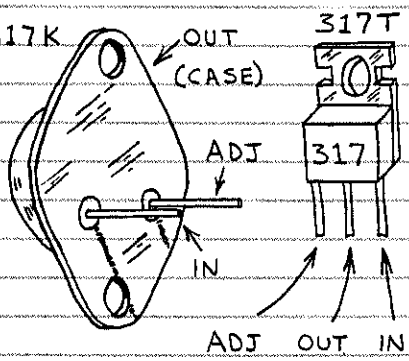
1 - IN
2 - OUT
3 - GROUND

CAUTION: AC LINE OPERATED CIRCUITS.

☐ VARIABLE OUTPUT POWER SUPPLY

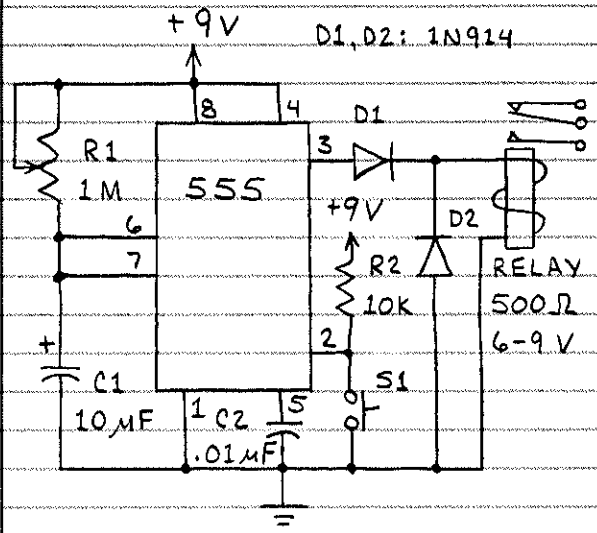


THIS ADJUSTABLE SUPPLY WILL DELIVER FROM 1.2 TO 37 VOLTS AT UP TO 1.5 AMPERES. R1 CONTROLS V_{OUT}. (IF V_{OUT} DOES NOT GO TO 1.2 VOLT MINIMUM, R1 MAY NOT BE ABLE TO ACHIEVE SUFFICIENTLY LOW RESISTANCE.) T1 SHOULD HAVE 25 VOLT (OR HIGHER) SECONDARY AND BE RATED FOR 2 AMPERES OR MORE.



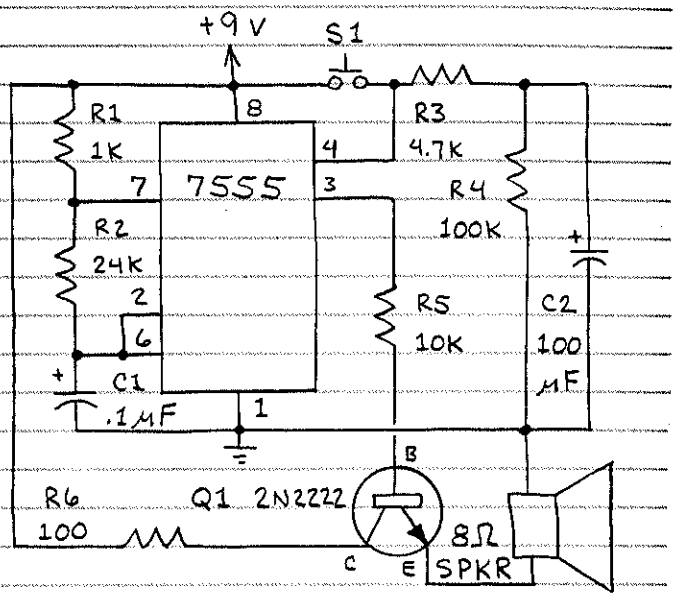
TIMER CIRCUITS

☐ BASIC TIMER



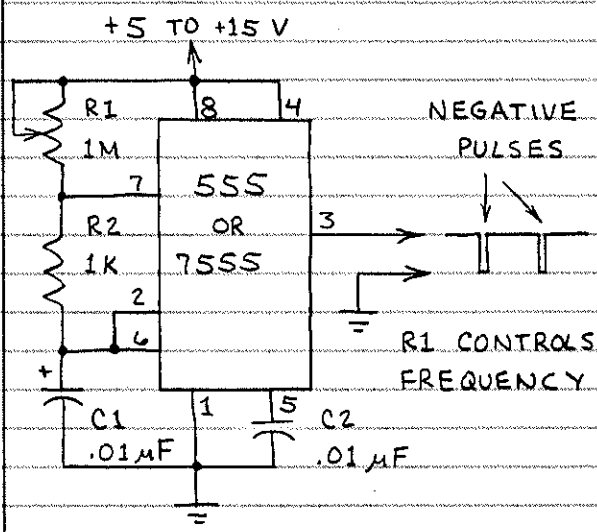
PRESS S1 MOMENTARILY TO START TIMING CYCLE. RELAY WILL BE ACTUATED (PULLED IN) UNTIL CYCLE IS COMPLETE. R1 AND C1 CONTROL LENGTH OF TIME DELAY. USE VERY LARGE VALUE FOR C1 TO GET LONG DELAYS. CIRCUIT WILL RESPOND TO LOGIC PULSES, TOO.

☐ TONE BURST GENERATOR



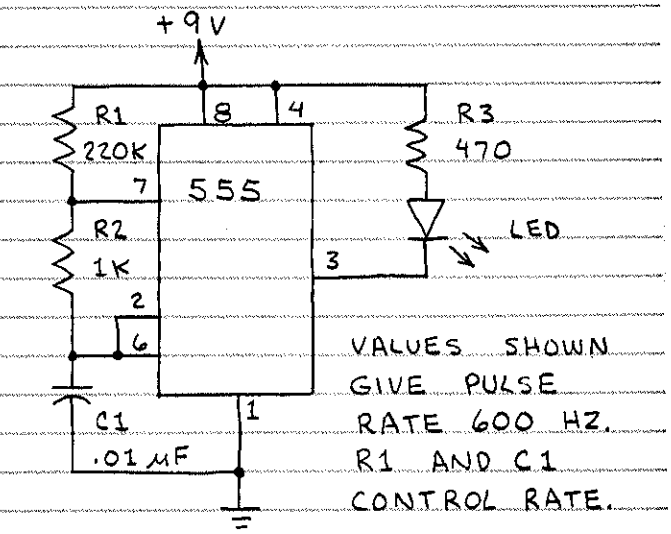
PRESS S1 AND THE SPEAKER EMITS A TONE. RELEASE S1 AND THE TONE CONTINUES FOR SEVERAL SECONDS. C2 AND R4 CONTROL DELAY. C1 CONTROLS FREQUENCY. (USE 7555 ONLY. 555 USES TOO MUCH CURRENT.)

☐ PULSE GENERATOR



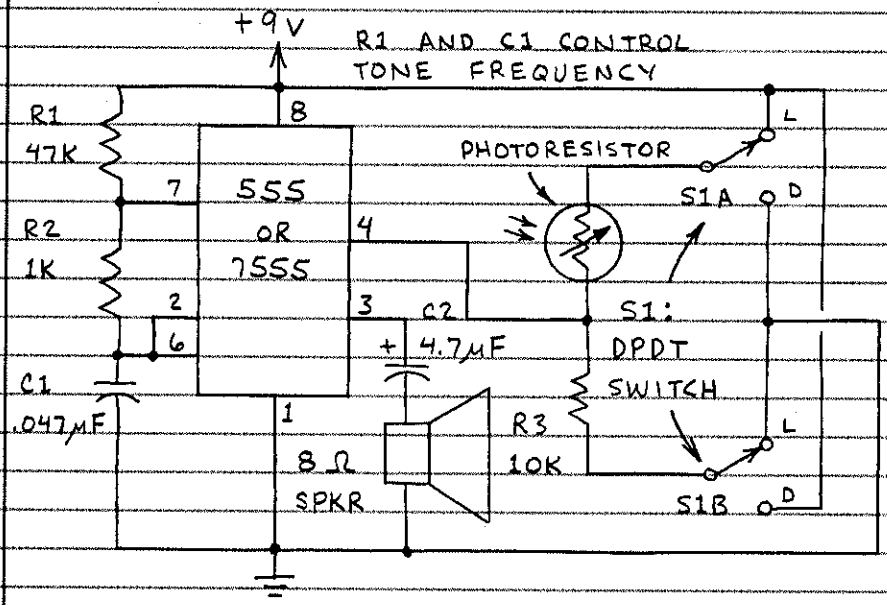
USE TO SUPPLY PULSES TO DIGITAL LOGIC CIRCUITS, ETC.

☐ LED TONE TRANSMITTER



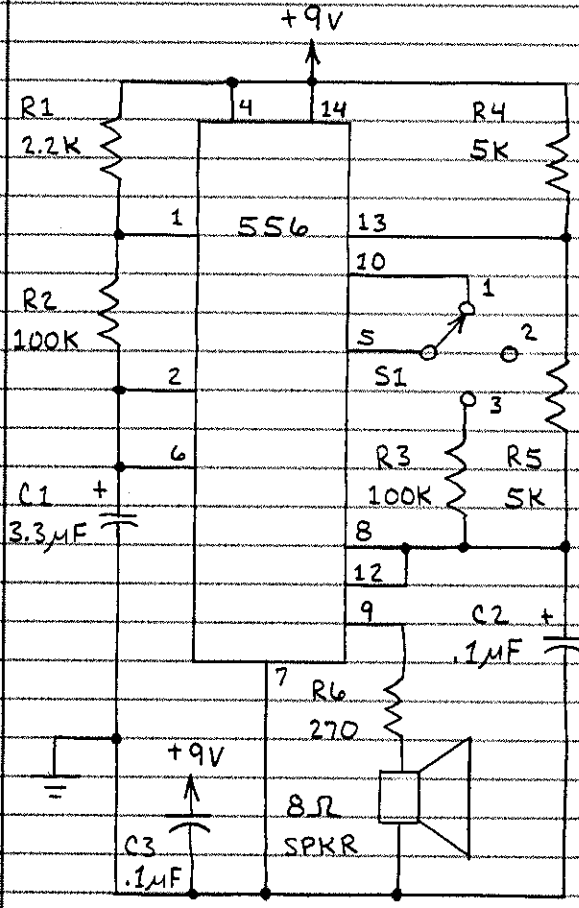
USE TO TEST LIGHTWAVE RECEIVERS.

☐ LIGHT / DARK DETECTOR



WHEN S1 IS IN POSITION "L," THE SPEAKER EMITS A TONE WHEN LIGHT ILLUMINATES THE PHOTORESISTOR. WHEN S1 IS IN POSITION "D," THE SPEAKER EMITS A TONE WHEN THE PHOTORESISTOR IS NOT ILLUMINATED.

☐ 3-STATE TONE GENERATOR



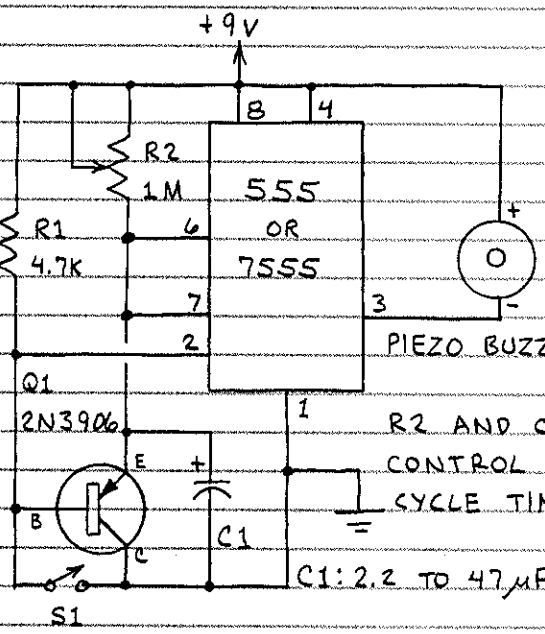
S1:

1 - TONE BURST

2 - STEADY TONE

3 - TWO TONE

☐ EVENT FAILURE ALARM



R2 AND C1 CONTROL CYCLE TIME.

C1: 2.2 TO 47μF

WHEN POWER IS APPLIED, THE 555 ENTERS A TIMING CYCLE. UNLESS S1 IS CLOSED BEFORE THE CYCLE ENDS, THE PIEZO BUZZER SOUNDS. THE CYCLE CAN BE RESET ANY TIME BY CLOSING S1. NOTE: S1 CAN BE REPLACED BY A SIGNAL FROM AN EXTERNAL CIRCUIT.

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