Engineer's Mini-Notebook

Basic Semiconductor Circuits

Forrest M. Mims III

Radio Shack
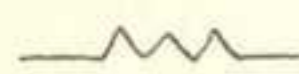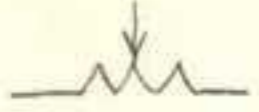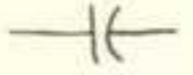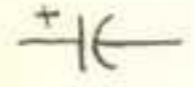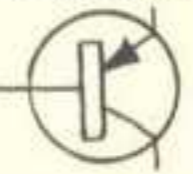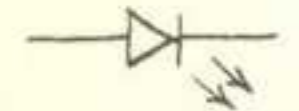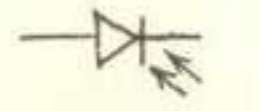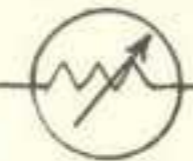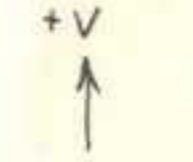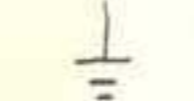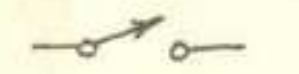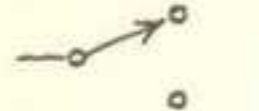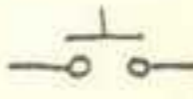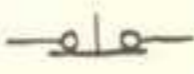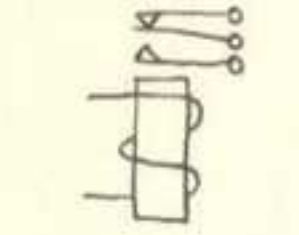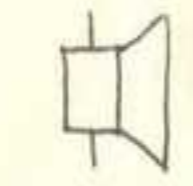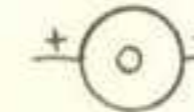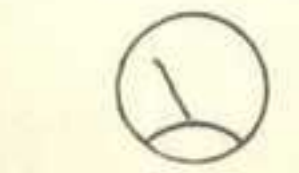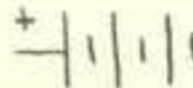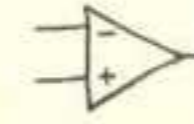
CIRCUIT SYMBOLS

FIXED RESISTOR	VARIABLE RESISTOR	FIXED CAPACITOR	POLARIZED CAPACITOR
RECTIFIER/ DIODE	ZENER DIODE	PNP TRANSISTOR	NPN TRANSISTOR
LED	SOLAR CELL	PHOTO- RESISTOR	PHOTO- TRANSISTOR
CONNECTED WIRES	UNCONNECTED WIRES	POSITIVE SUPPLY	GROUND
SPST SWITCH	SPDT SWITCH	NORMALLY OPEN PUSHBUTTON	NORMALLY CLOSED PUSHBUTTON
RELAY	TRANSFORMER	SPEAKER	PIEZO- SPEAKER
METER	LAMP	BATTERY	OP-AMP

ENGINEER'S MINI-NOTEBOOK

BASIC SEMICONDUCTOR CIRCUITS

BY

FORREST M. MIMS, III

THIS BOOK INCLUDES STANDARD APPLICATION
CIRCUITS AND CIRCUITS DESIGNED BY THE
AUTHOR. EACH CIRCUIT WAS ASSEMBLED AND
TESTED BY THE AUTHOR AS THE BOOK WAS
DEVELOPED. AFTER THE BOOK WAS COMPLETED,
THE AUTHOR REASSEMBLED EACH CIRCUIT TO
CHECK FOR ERRORS. WHILE REASONABLE CARE
WAS EXERCISED IN THE PREPARATION OF THIS
BOOK, VARIATIONS IN COMPONENT TOLERANCES
AND CONSTRUCTION METHODS MAY CAUSE THE
RESULTS YOU OBTAIN TO DIFFER FROM THOSE
GIVEN HERE. THEREFORE THE AUTHOR AND
RADIO SHACK ASSUME NO RESPONSIBILITY FOR
THE SUITABILITY OF THIS BOOK'S CONTENTS
FOR ANY APPLICATION. SINCE WE HAVE NO
CONTROL OVER THE USE TO WHICH THE
INFORMATION IN THIS BOOK IS PUT, WE
ASSUME NO LIABILITY FOR ANY DAMAGES
RESULTING FROM ITS USE. OF COURSE IT
IS YOUR RESPONSIBILITY TO DETERMINE IF
COMMERCIAL USE, SALE OR MANUFACTURE
OF ANY DEVICE THAT INCORPORATES INFOR-
MATION IN THIS BOOK INFRINGES ANY
PATENTS, COPYRIGHTS OR OTHER RIGHTS.

DUE TO THE MANY INQUIRIES RECEIVED BY
RADIO SHACK AND THE AUTHOR, IT IS NOT
POSSIBLE TO PROVIDE PERSONAL RESPONSES
TO REQUESTS FOR ADDITIONAL INFORMATION
(CUSTOM CIRCUIT DESIGN, TECHNICAL ADVICE,
TROUBLESHOOTING ADVICE, ETC.). IF YOU
WISH TO LEARN MORE ABOUT ELECTRONICS,
SEE OTHER BOOKS IN THIS SERIES AND
RADIO SHACK'S "GETTING STARTED IN
ELECTRONICS." ALSO, READ MAGAZINES LIKE
MODERN ELECTRONICS AND RADIO-ELECTRONICS.
THE AUTHOR WRITES A MONTHLY COLUMN,
"ELECTRONICS NOTEBOOK," FOR MODERN ELECTRONICS.

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CONTENTS

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INTRODUCTION

IN THIS ERA OF INTEGRATED CIRCUIT MICROCHIPS, THE SIMPLICITY AND ECONOMY OF CIRCUITS MADE FROM INDIVIDUAL COMPONENTS ARE OFTEN OVERLOOKED. THE CIRCUITS THAT FOLLOW ILLUSTRATE MORE THAN 75 APPLICATIONS FOR SUCH BASIC COMPONENTS AS DIODES, TRANSISTORS, SCRS, AND TRIACS. THESE CIRCUITS ARE PRECEEDED BY SECTIONS ON RESISTORS AND CAPACITORS SINCE THESE COMPONENTS ARE AN ESSENTIAL INGREDIENT IN NEARLY ALL SEMICONDUCTOR CIRCUITS.

FOR MORE INFORMATION ABOUT THE COMPONENTS USED IN THE CIRCUITS THAT FOLLOW, SEE "GETTING STARTED IN ELECTRONICS" (RADIO SHACK, 1983). THIS BOOK COVERS BASIC ELECTRONICS AND INCLUDES 100 TESTED CIRCUITS. ALSO, SEE OTHER TITLES IN THE "ENGINEER'S MINI-NOTEBOOK" SERIES.

CIRCUIT ASSEMBLY TIPS

TEST VERSIONS OF THE CIRCUITS IN THIS BOOK WERE ASSEMBLED ON RADIO SHACK MODULAR BREADBOARD SOCKETS. AFTER ASSEMBLING AND TESTING A CIRCUIT ON A BREADBOARD, YOU CAN ASSEMBLE A PERMANENT VERSION ON A CIRCUIT BOARD AND INSTALL IT IN AN ENCLOSURE. THOUGH EACH CIRCUIT INCLUDES SPECIFIC COMPONENT VALUES, SUBSTITUTIONS ARE USUALLY OK IF VOLTAGE, CURRENT, AND POWER RATINGS ARE OBSERVED. FOR INSTANCE, A 1.2K RESISTOR CAN USUALLY BE SUBSTITUTED FOR A 1K UNIT. A 100K POTENTIOMETER CAN BE USED IN PLACE OF A 50K UNIT. AND MANY NPN TRANSISTORS CAN BE USED FOR THE POPULAR 2N2222. FOR MORE, SEE "GETTING STARTED IN ELECTRONICS."

RESISTORS

RESISTORS RESIST THE FLOW OF AN ELECTRICAL CURRENT. THE UNIT OF RESISTANCE IS THE <u>OHM</u> (Ω). A POTENTIAL DIFFERENCE OF ONE VOLT WILL FORCE A CURRENT OF ONE AMPERE THROUGH A RESISTANCE OF ONE OHM.

OHM'S LAW

<u>VOLTAGE</u> (V) IS THE POTENTIAL DIFFERENCE ACROSS A RESISTOR. <u>CURRENT</u> (I) IS THE FLOW OF ELECTRONS THROUGH A RESISTOR. GIVEN ANY TWO VALUES OF RESISTANCE, VOLTAGE, OR CURRENT, THE THIRD VALUE CAN BE CALCULATED FROM OHM'S LAW:

$$V = I \times R \qquad I = V/R \qquad R = V/I$$

THE <u>POWER</u> DISSIPATED IN A RESISTOR CAN ALSO BE CALCULATED:

$$P = V \times I \qquad P = I^2 R$$

THE UNIT OF POWER IS THE <u>WATT</u>. IT IS IMPORTANT TO BE SURE THAT ALL VALUES ARE EXPRESSED PROPERLY WHEN USING OHM'S LAW. FOR EXAMPLE, 65 MILLIVOLTS SHOULD BE EXPRESSED AS 0.065 VOLTS. 470 MILLIWATTS SHOULD BE EXPRESSED AS 0.47 WATTS. A 47K RESISTOR HAS A RESISTANCE OF 47 × 1,000 OR 47,000 OHMS. A 2.2M RESISTOR HAS A RESISTANCE OF 2.2 × 1,000,000 OR 2,200,000 OHMS.

USUALLY YOU MAY USE A RESISTOR WITH A VALUE WITHIN 10-20% OF THE REQUIRED VALUE. <u>ALWAYS</u> USE RESISTORS HAVING THE PROPER POWER RATING.

RESISTORS IN SERIES
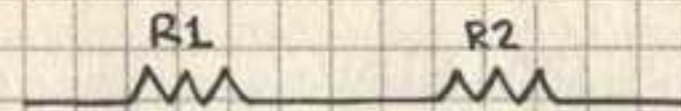
TOTAL RESISTANCE (R_T) = R1 + R2
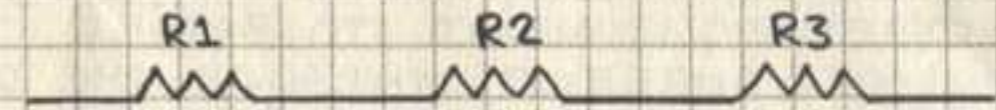
TOTAL RESISTANCE (R_T) = R1 + R2 + R3

RESISTORS IN PARALLEL

$$R_T = \frac{R1 \times R2}{R1 + R2}$$

$$R_T = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}}$$
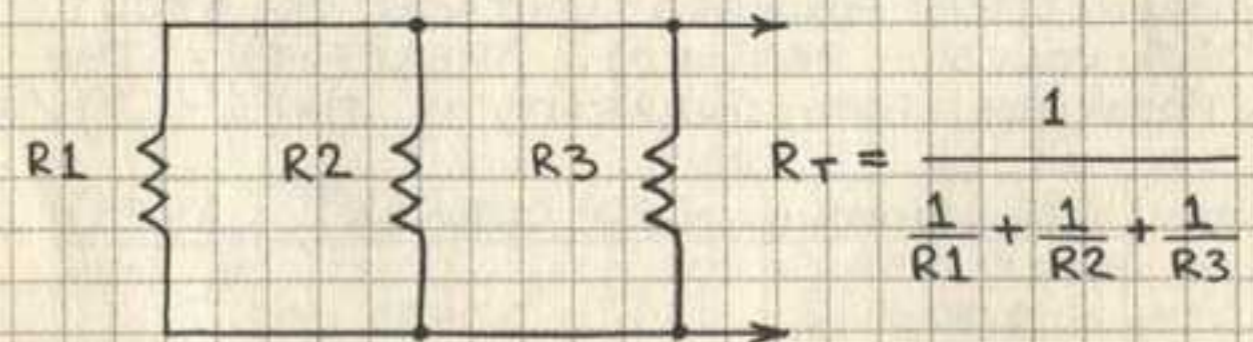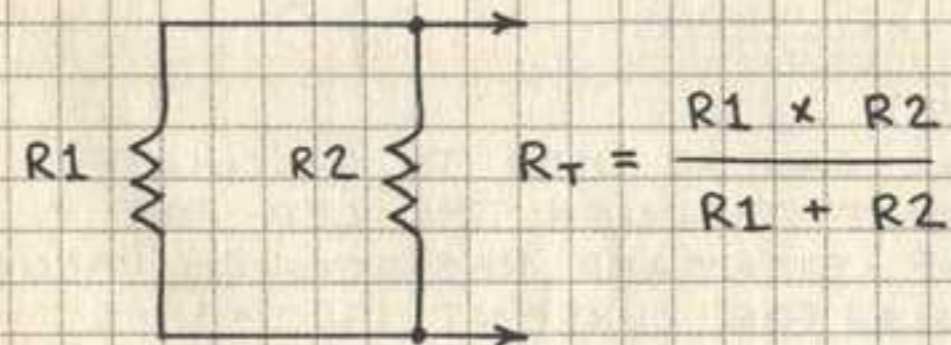
IF R1 = R2 = R3, THEN R_T = R1 / 3.

RESISTORS IN SERIES/PARALLEL

$$R_T = \frac{R1 \times R2}{R1 + R2} + R3$$
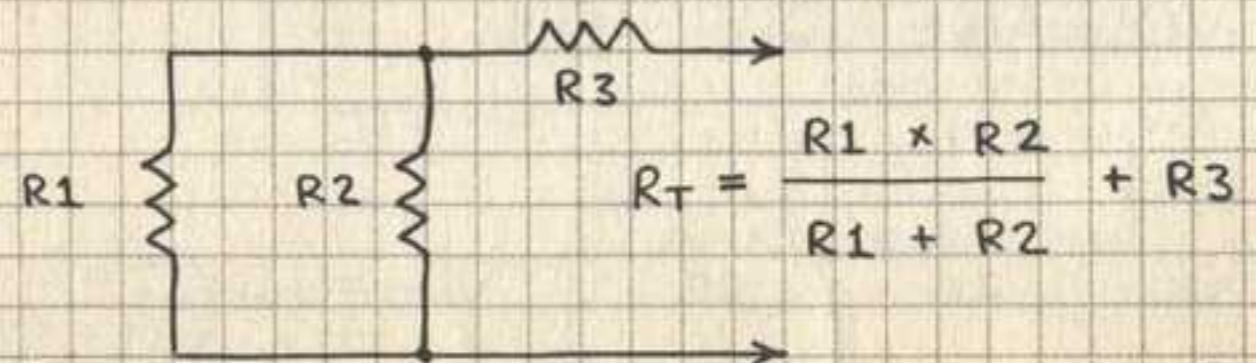
HOW TO USE RESISTORS

CURRENT LIMITING

A RESISTOR CAN BE PLACED IN SERIES
WITH A LAMP, LED, SPEAKER, TRANSISTOR,
OR OTHER COMPONENT TO REDUCE THE
FLOW OF CURRENT THROUGH THE DEVICE.
FOR EXAMPLE:
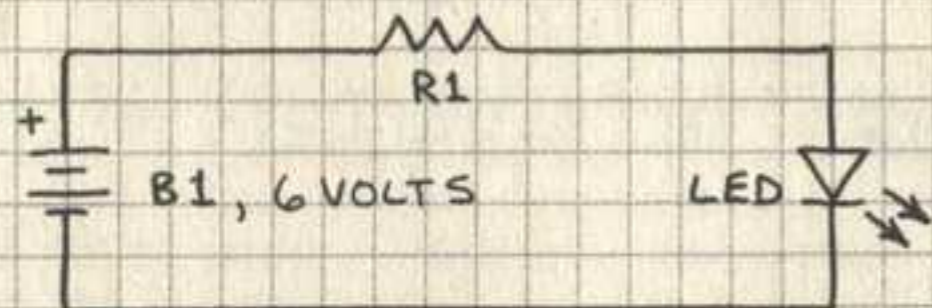
OHM'S LAW CAN BE USED TO CALCULATE
THE CURRENT THROUGH THE LED FOR A
RANGE OF STANDARD RESISTANCE VALUES.
THE FORMULA FOR CURRENT IS $I = V/R$.
AN LED DOES NOT BEGIN TO CONDUCT
UNTIL THE FORWARD VOLTAGE IS ABOUT
1.7 VOLTS (RED LED). THEREFORE, THE
FORMULA FOR CURRENT IS $I = (6-1.7)/R$.

R1 (OHMS	LED CURRENT (AMPS)
100	.043
150	.029
220	.020
270	.016
330	.013

VOLTAGE DIVISION

$$V_{OUT} = V_{IN} \left(\frac{R2}{R1 + R2} \right)$$

8
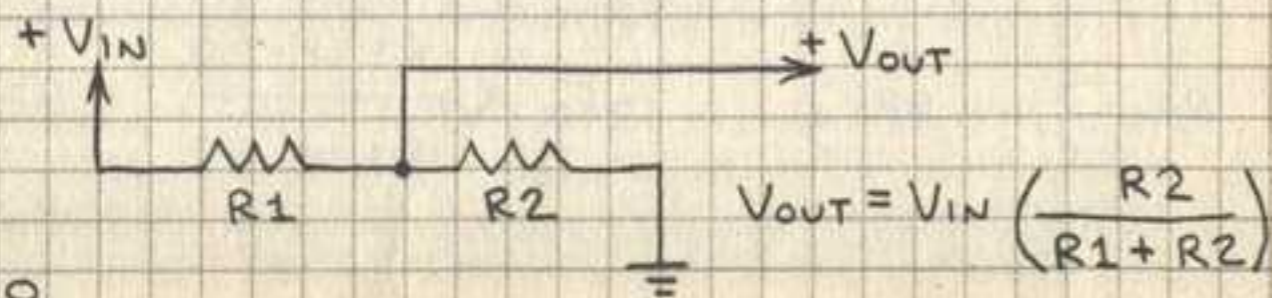
WHEATSTONE BRIDGE

THE WHEATSTONE BRIDGE PERMITS VERY
ACCURATE MEASUREMENTS OF RESISTANCE.
HERE IS THE BASIC CIRCUIT:
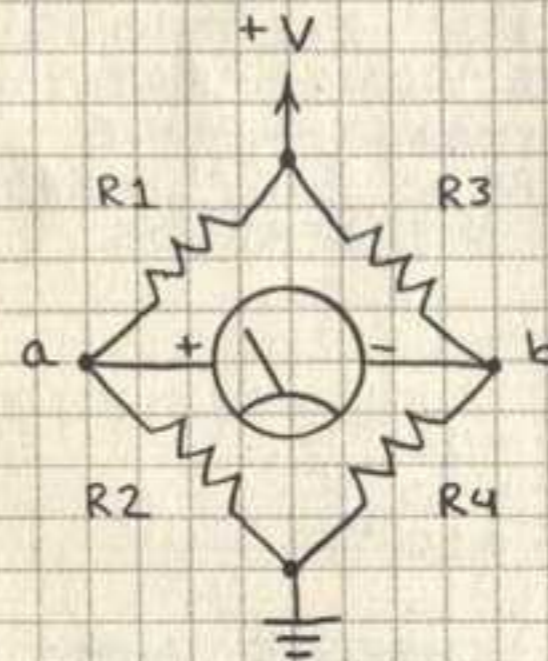
R1-R2 AND R3-R4
FORM TWO VOLTAGE
DIVIDERS. WHEN THE
VOLTAGE AT a EQUALS
THE VOLTAGE AT b,
THE METER INDICATES
NO VOLTAGE AND THE
BRIDGE IS SAID TO BE
BALANCED. WHEN THIS
OCCURS, THEN:
$R1/R3 = R2/R4$.
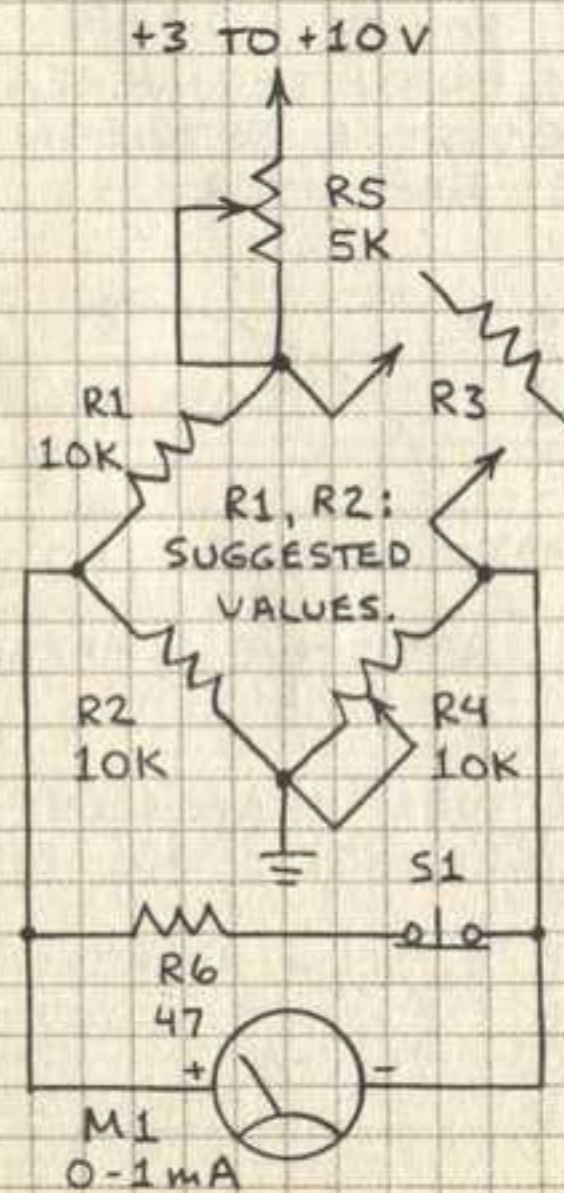
THE BRIDGE SHOWN
HERE PERMITS THE
ACCURATE MEASURE-
MENT OF AN UN-
KNOWN RESISTANCE
(R3). R1 AND R2
SHOULD BE PRECISION
(±1%) RESISTORS. R4
IS A POTENTIOMETER
WITH A CALIBRATED
DIAL. R5 IS USED
TO REGULATE THE
CURRENT FROM THE
POWER SUPPLY. R6
AND S1 FORM A
SHUNT THAT PROTECTS
M1. ADJUST R4 UNTIL
M1 = 0. PRESS S1
AND REPEAT. R3 = R4.
IF R1 ≠ R2, THEN
$R3 = (R1 \times R4)/R2$.

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CAPACITORS

CAPACITORS STORE AN ELECTRICAL CHARGE. THE UNIT OF CAPACITANCE IS THE <u>FARAD</u>. A 1-FARAD CAPACITOR CONNECTED TO A 1-VOLT SUPPLY WILL STORE A CHARGE OF 6.28×10^{18} ELECTRONS. MOST CAPACITORS HAVE CONSIDERABLY LESS CAPACITY. VALUES COMMONLY RANGE FROM A FEW PICOFARADS (10^{-12} FARAD) TO A FEW THOUSAND MICROFARADS (10^{-6} FARAD).

1 FARAD = 1 F
1 MICROFARAD = $1 \mu F = 10^{-6} F$
1 NANOFARAD = $1 nF = 10^{-9} F$
1 PICOFARAD = $1 pF = 10^{-12} F$

A CAPACITOR CAN BE CHARGED ALMOST INSTANTLY BY CONNECTING ITS LEADS DIRECTLY ACROSS A POWER SUPPLY. THE CHARGING TIME CAN BE INCREASED BY INSERTING A RESISTOR BETWEEN THE SUPPLY AND THE CAPACITOR.
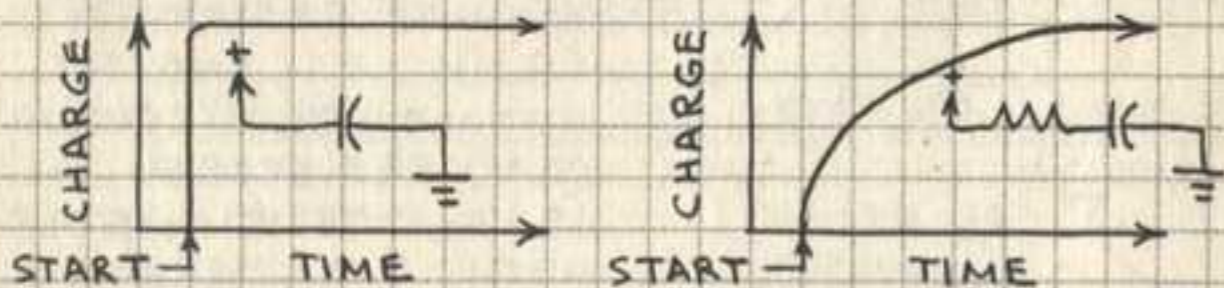
DIRECT CHARGE   RESISTIVE CHARGE

A CHARGED CAPACITOR WILL GRADUALLY LOSE ITS CHARGE THROUGH LEAKAGE. THE DISCHARGE TIME CAN BE REDUCED BY CONNECTING A RESISTOR ACROSS THE CAPACITOR'S TWO LEADS:

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CAPACITORS IN SERIES

TOTAL CAPACITANCE $(C_T) = \dfrac{C1 \times C2}{C1 + C2}$

TOTAL CAPACITANCE $(C_T) = \dfrac{1}{\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}}$
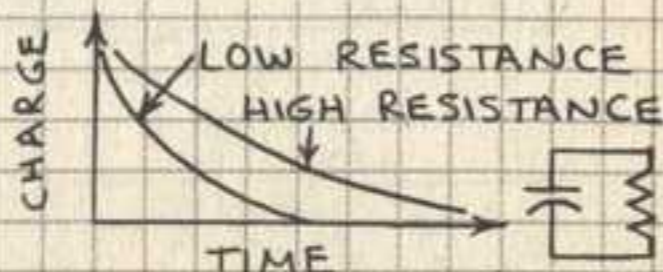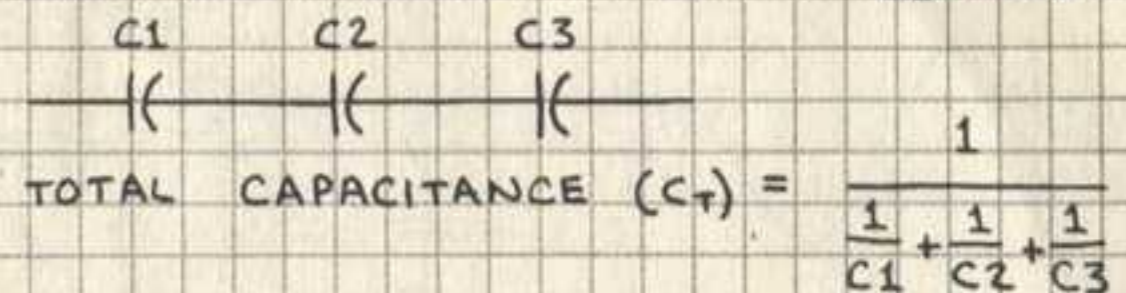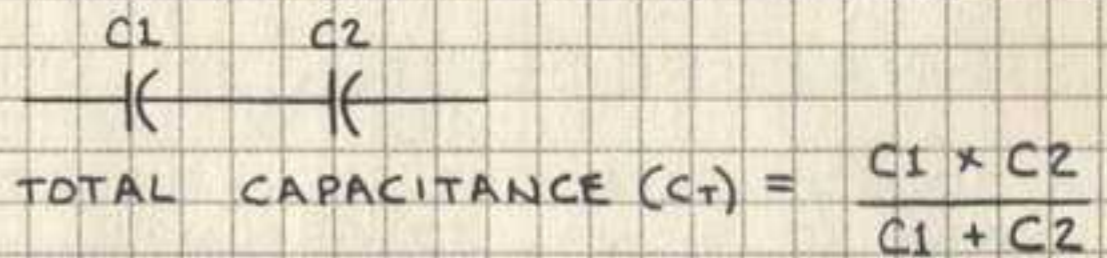
CAPACITORS IN PARALLEL

$C_T = C1 + C2$

$C_T = C1 + C2 + C3$
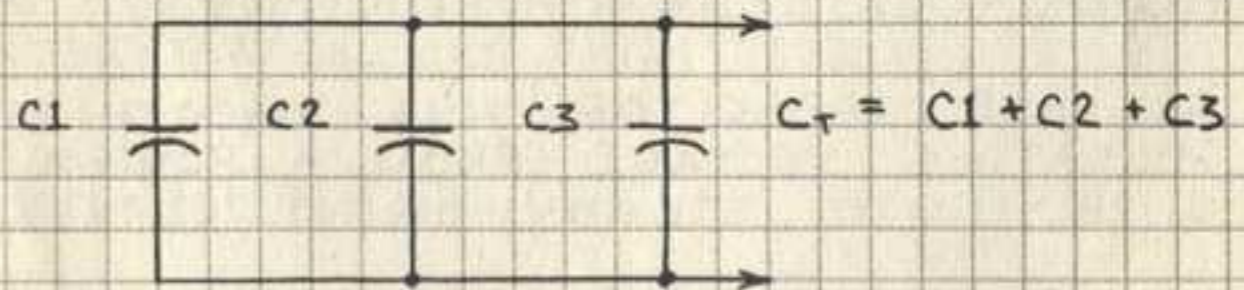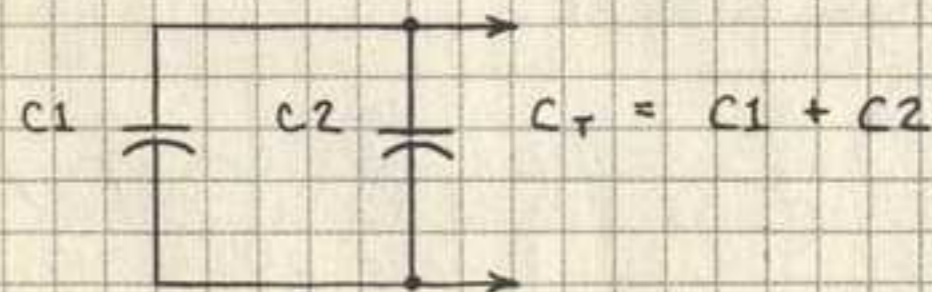
<u>WARNING!</u>

MOST CAPACITORS CAN RETAIN A CHARGE FOR A CONSIDERABLE TIME AFTER THE CHARGING SUPPLY HAS BEEN SWITCHED OFF. THEREFORE <u>USE CAUTION</u> WHEN WORKING WITH CAPACITORS. A LARGE ELECTROLYTIC CAPACITOR CHARGED TO ONLY 5 TO 10 VOLTS CAN MELT THE TIP OF A SCREWDRIVER SHORTED ACROSS ITS LEADS! HIGH-VOLTAGE CAPACITORS IN TV SETS AND PHOTOFLASH UNITS CAN STORE A <u>LETHAL</u> CHARGE!

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HOW TO USE CAPACITORS

SIGNAL FILTERING

A SINGLE CAPACITOR CAN DIVERT AN UNWANTED SIGNAL TO GROUND:
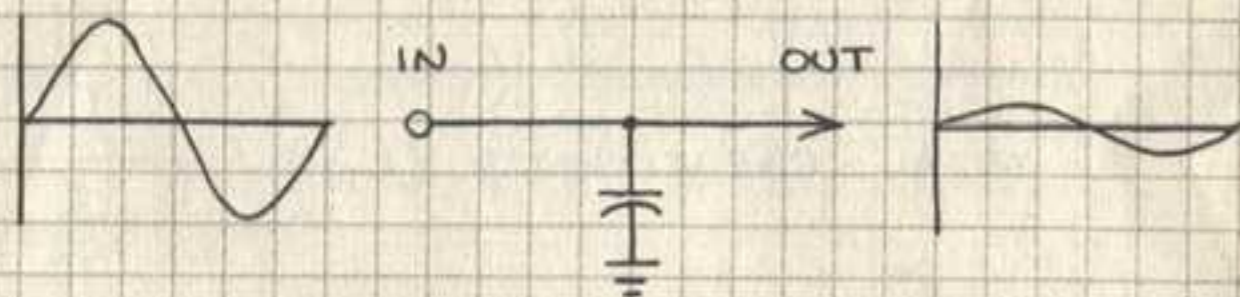
A SINGLE CAPACITOR CAN REMOVE AN UNWANTED DC COMPONENT FROM A FLUCTUATING SIGNAL:
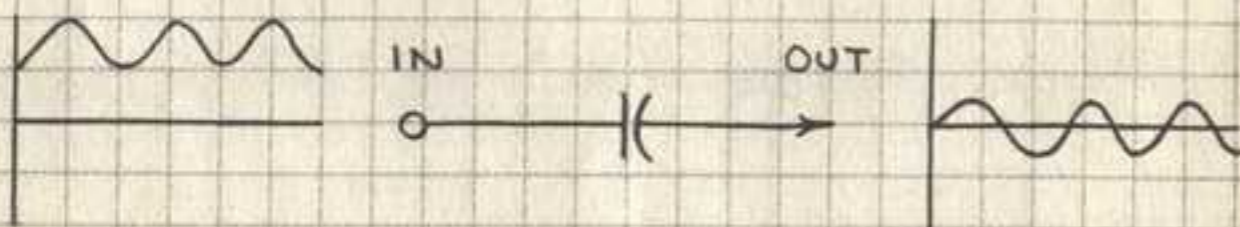
POWER SUPPLY FILTERING

A LARGE CAPACITOR WILL SMOOTH THE PULSATING VOLTAGE FROM A POWER SUPPLY INTO STEADY DIRECT CURRENT:
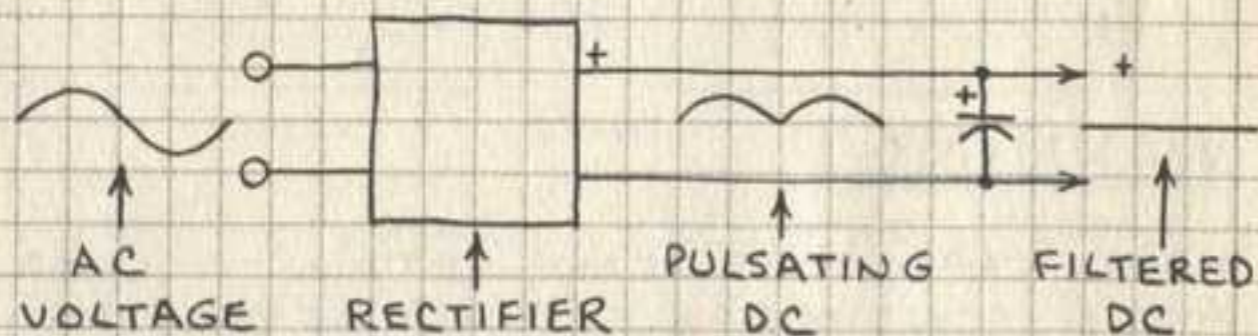
SPIKE AND NOISE SUPPRESSION

A 0.1 μF CAPACITOR ACROSS THE POWER SUPPLY PINS OF A LOGIC CHIP WILL HELP SUPPRESS FALSE TRIGGERING CAUSED BY BRIEF POWER SUPPLY NOISE SPIKES.

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RESISTOR-CAPACITOR CIRCUITS

AMONG THE MOST IMPORTANT OF ALL CIRCUITS ARE THE BASIC RESISTOR-CAPACITOR (RC) CIRCUITS:

INTEGRATOR

THE INTEGRATOR IS AN RC CIRCUIT THAT TRANSFORMS AN INCOMING SQUARE WAVE INTO A TRIANGLE WAVE:
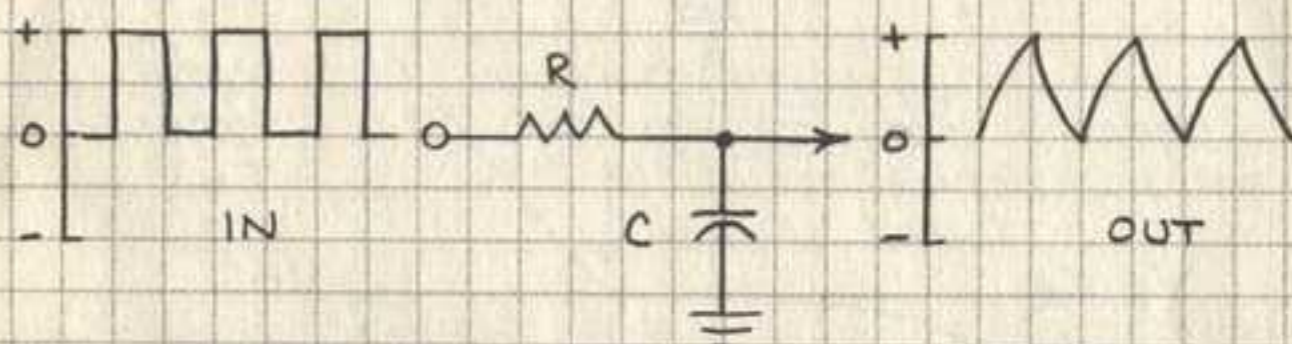
$R \times C$ IS THE TIME CONSTANT OF THE CIRCUIT. RC MUST BE AT LEAST 10 TIMES THE PERIOD OF THE INPUT SIGNAL. IF NOT, THE AMPLITUDE OF THE OUTPUT SIGNAL WILL BE REDUCED. THE CIRCUIT WILL THEN BE A LOW-PASS FILTER THAT BLOCKS HIGH FREQUENCIES.

DIFFERENTIATOR

THE DIFFERENTIATOR IS AN RC CIRCUIT THAT TRANSFORMS AN INCOMING SQUARE WAVE INTO A PULSED OR SPIKED WAVEFORM:
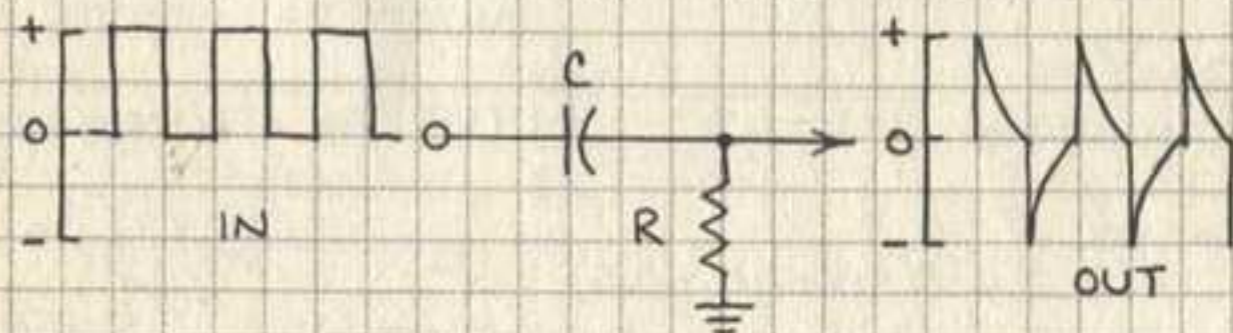
THE RC TIME CONSTANT SHOULD BE 1/10 (OR LESS) OF THE DURATION OF THE INCOMING PULSES. DIFFERENTIATORS ARE OFTEN USED TO CREATE TRIGGER PULSES.

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DIODES AND RECTIFIERS

DIODES AND RECTIFIERS ARE SEMICONDUCTOR DEVICES THAT CONDUCT ELECTRICITY IN ONLY ONE DIRECTION. IT IS IMPORTANT TO UNDERSTAND THAT A DIODE DOES NOT BEGIN TO CONDUCT UNTIL THE FORWARD VOLTAGE REACHES A THRESHOLD POINT. FOR SILICON DIODES THIS VOLTAGE IS ABOUT 0.6 VOLT. FOR GERMANIUM DIODES IT IS ABOUT 0.3 VOLT. THIS GRAPH SUMS UP DIODE OPERATION:

0.6 VOLT (SILICON)

AVOID EXCESS I_F!

AVOID EXCESS V_R!

I_F = FORWARD CURRENT
I_R = REVERSE CURRENT
V_F = FORWARD VOLTAGE
V_R = REVERSE VOLTAGE

VOLTAGE DROPPER

D1 → $V = V - 0.6$

D2 → $V = V - 1.2$

Dn → $V = V - (n \times 0.6)$

LOAD (R_L)

D1, D2, D3 = 1N914
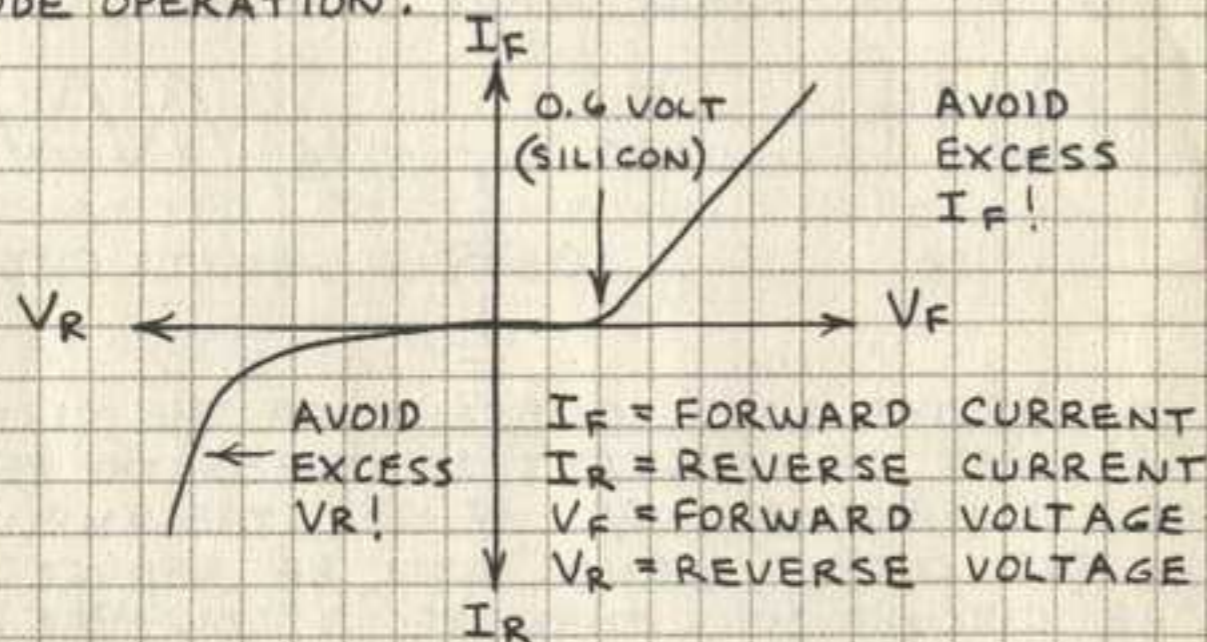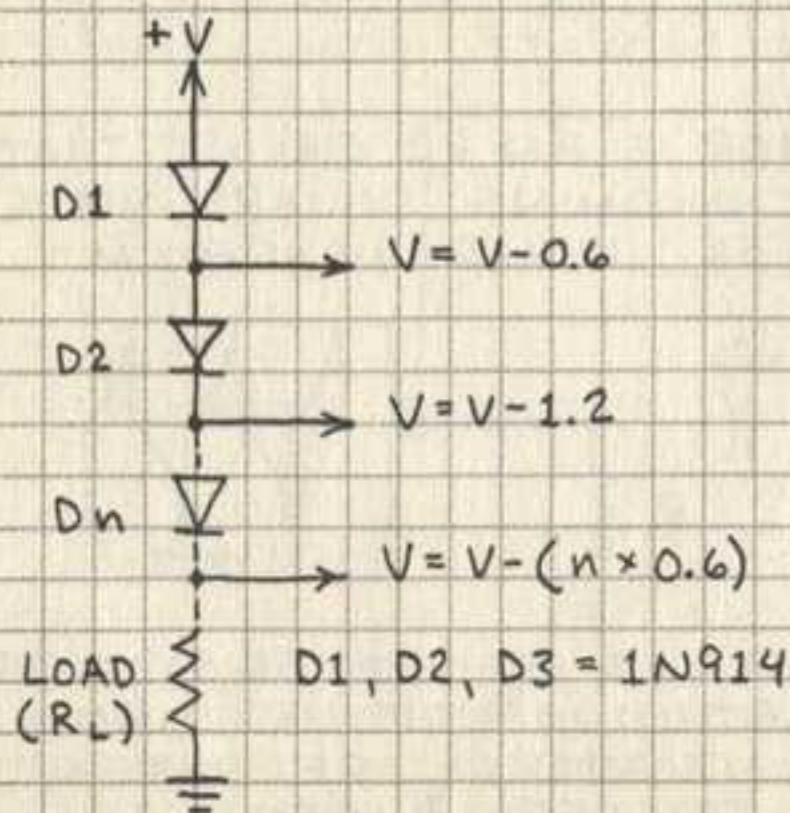
THIS CIRCUIT WILL REDUCE VOLTAGE FROM A POWER SUPPLY BY 0.6 VOLT PER DIODE.

TYPICAL APPLICATION:

1N914

6V → 5.4V
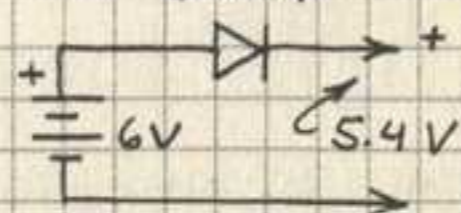
ALLOWS 6-VOLTS TO POWER TTL CHIP.

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VOLTAGE REGULATOR

$+ V_{IN}$

R1

$+ V_{OUT}$

D1

D2

Dn

LOAD (R_L)
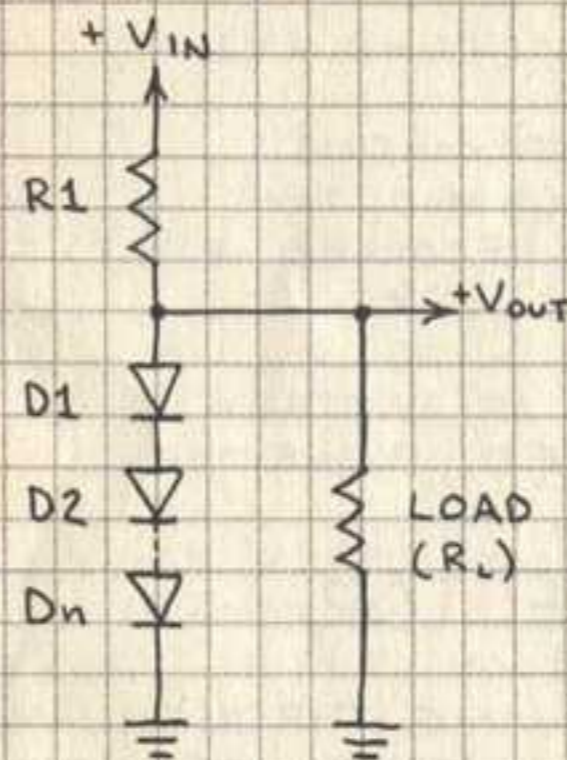
THIS CIRCUIT WILL SUPPLY A STEADY OUTPUT VOLTAGE EQUAL TO THE SUM OF THE TURN-ON (THRESHOLD) VOLTAGE OF DIODES D1 – Dn. THEREFORE,

$V_{OUT} = 0.6 \times (D1 + D2 + D_n)$.

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

CAUTION: D1 AND R1 MUST HAVE PROPER POWER RATING. (USE OHM'S LAW.)

TRIANGLE-TO-SINE WAVE

R1 10K

D1   D2

± 2.5-VOLT TRIANGLE WAVE   D1, D2 = 1N914   ± 0.5-VOLT SINE WAVE

PEAK-READING VOLTMETER

PEAK

D1 1N914   R1 1K

M1 0-1 mA   C1 1µF
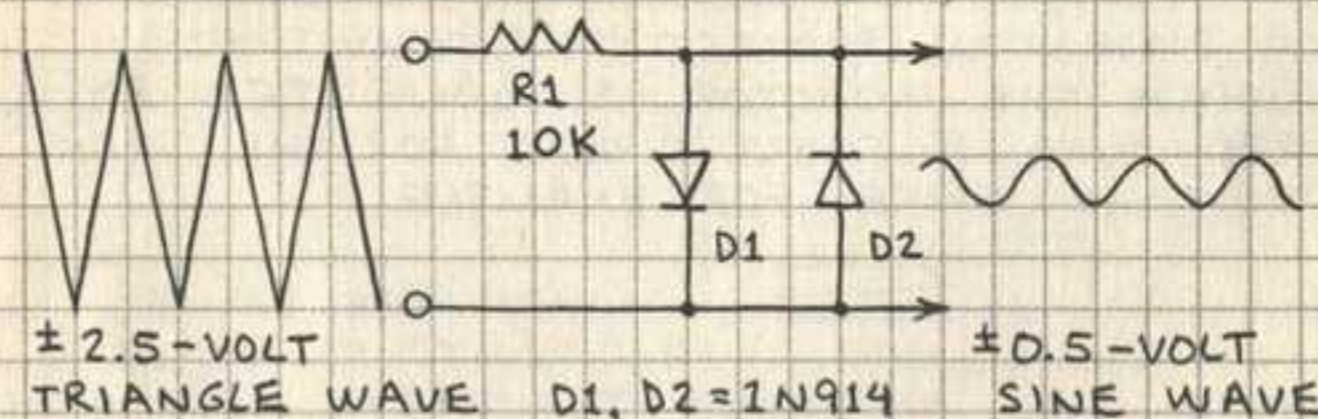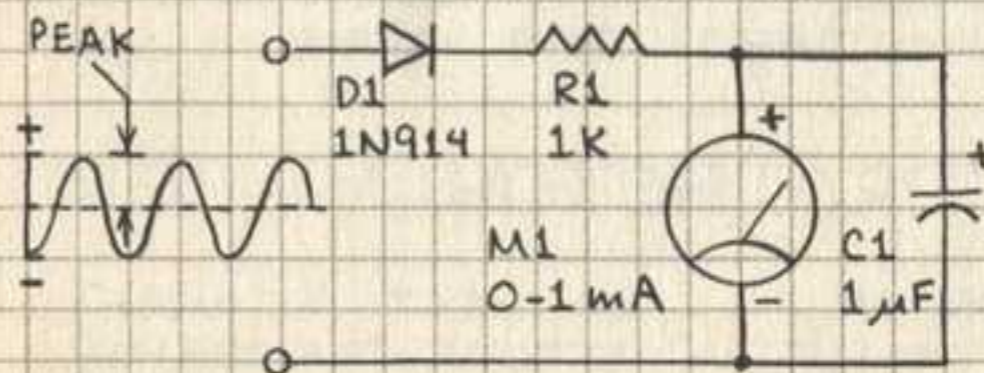
FOR BEST RESULTS, USE DIGITAL MULTIMETER FOR M1. SET TO READ VOLTAGE.

FREQUENCY OF INCOMING SIGNAL MUST BE HIGH ENOUGH TO KEEP C1 CHARGED.

115

REVERSE-POLARITY PROTECTOR
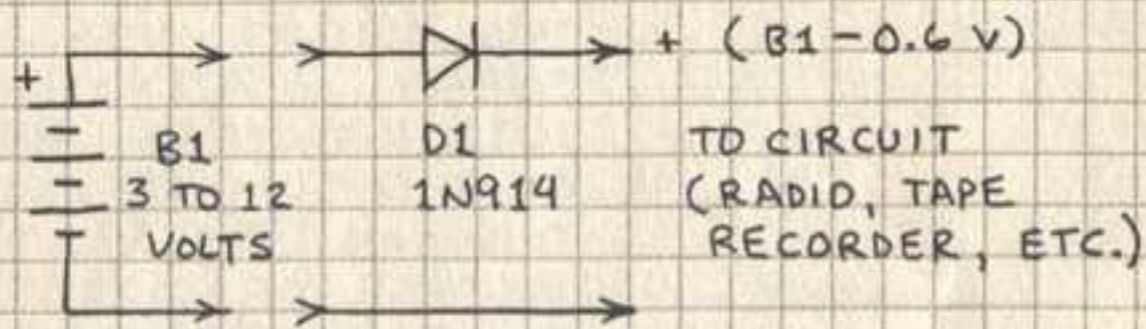
DIODE PROTECTS CIRCUIT IF BATTERY IS
INSTALLED WITH REVERSED POLARITY.

TRANSIENT PROTECTOR

WHEN THE CURRENT FLOWING THROUGH AN
INDUCTOR IS SUDDENLY SWITCHED OFF, THE
COLLAPSING MAGNETIC FIELD WILL GENERATE
A HIGH VOLTAGE IN THE INDUCTOR'S COILS.
THIS VOLTAGE SPIKE MAY HAVE AN AMPLITUDE
OF HUNDREDS OR EVEN THOUSANDS OF VOLTS.
A DIODE CAN PROTECT THE CIRCUIT TO
WHICH THE INDUCTOR IS CONNECTED BY
PROVIDING A SHORT CIRCUIT FOR THE HIGH
VOLTAGE SPIKE. FOR EXAMPLE:

WHEN THE DRIVE
CIRCUIT SWITCHES
THE RELAY OFF, A
HIGH-VOLTAGE SPIKE
IS GENERATED IN
THE RELAY'S COIL.
D1 SHORT CIRCUITS
THIS SPIKE.
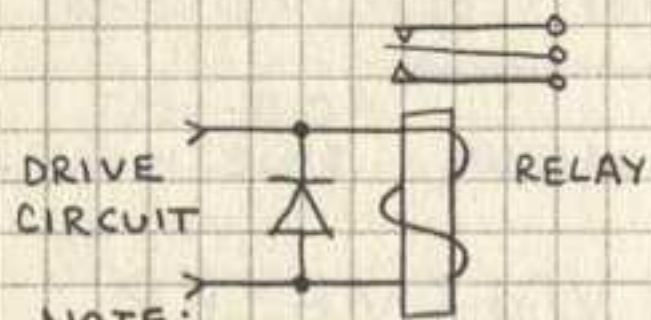
NOTE:
D1 INEFFECTIVE
DURING TURN-ON TIME.

METER PROTECTOR
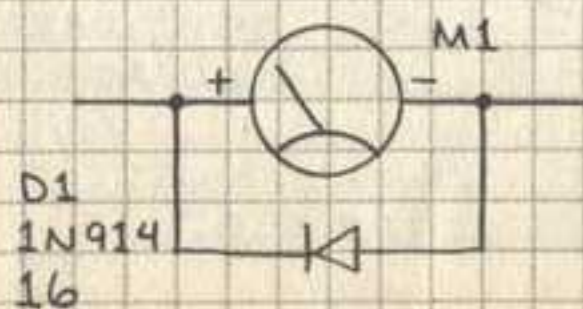
CONNECT A DIODE
ACROSS THE TERMI-
NALS OF A METER
TO PROVIDE REVERSE
CURRENT PROTECTION.

16

ADJUSTABLE WAVEFORM CLIPPER
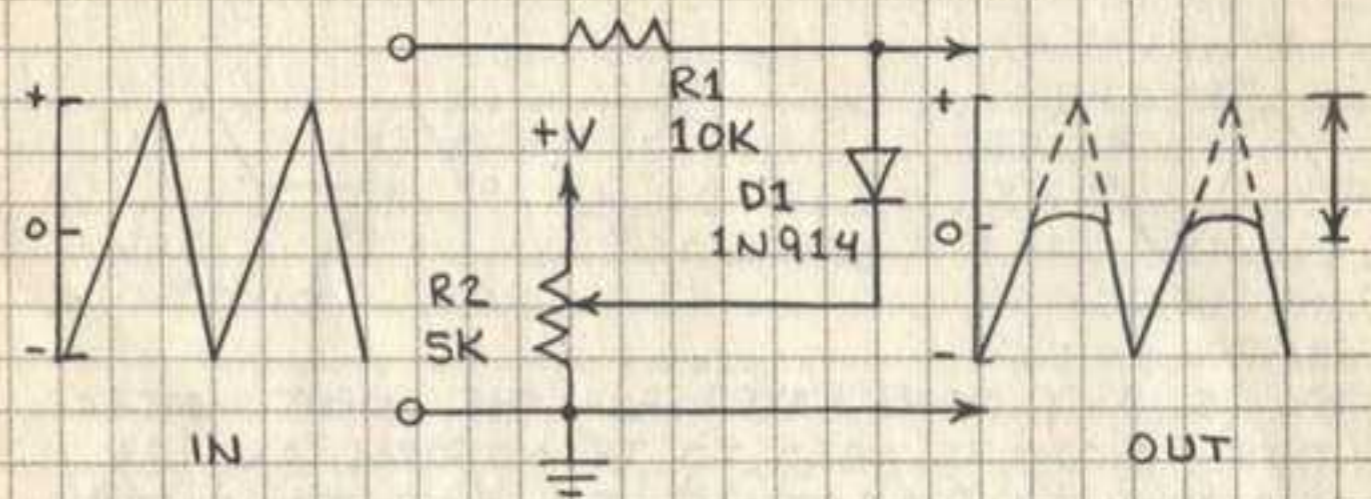
ADJUST R2 TO CONTROL CLIPPING AMPLITUDE.
+V SHOULD BE A VOLT OR SO HIGHER THAN
PEAK INPUT VOLTAGE.

ADJUSTABLE ATTENUATOR
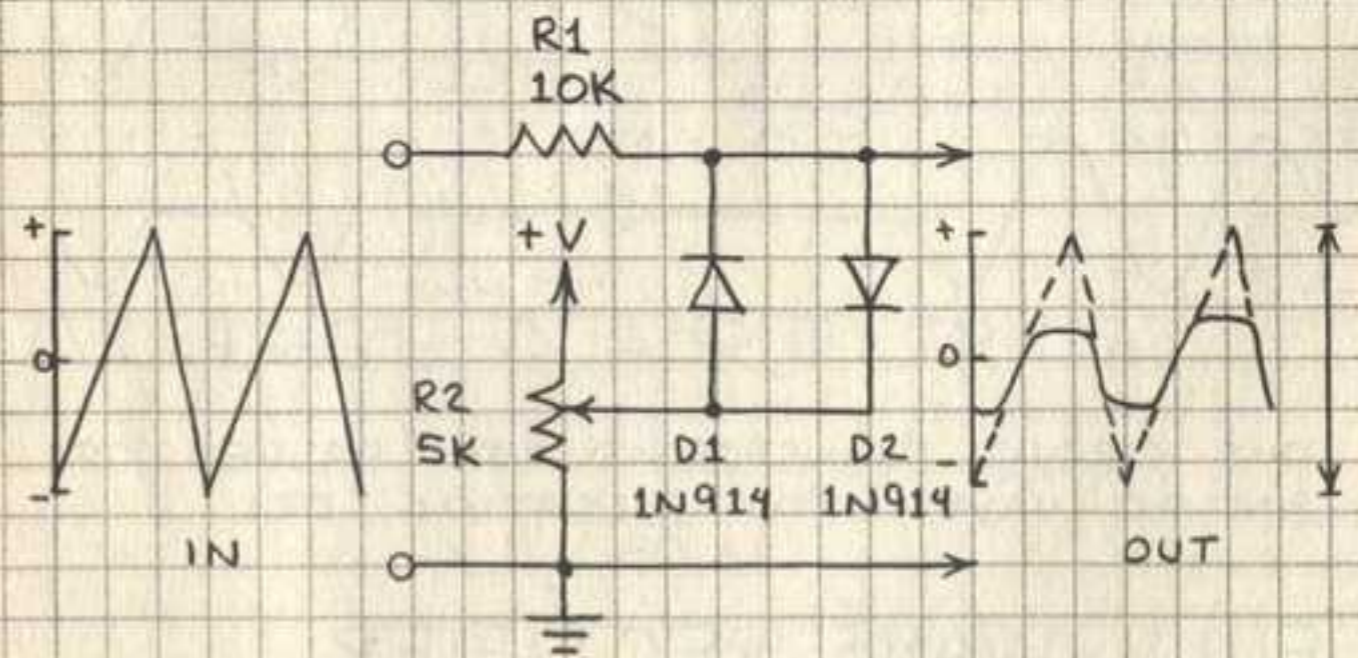
THIS IS A BIPOLARITY (+/-) VERSION OF
THE ADJUSTABLE CLIPPER.

AUDIO LIMITER
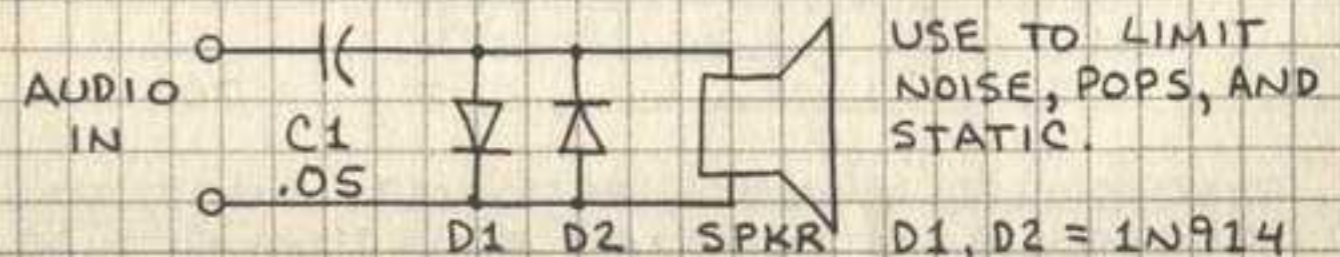
USE TO LIMIT
NOISE, POPS, AND
STATIC.

D1, D2 = 1N914

17

HALF-WAVE RECTIFIER
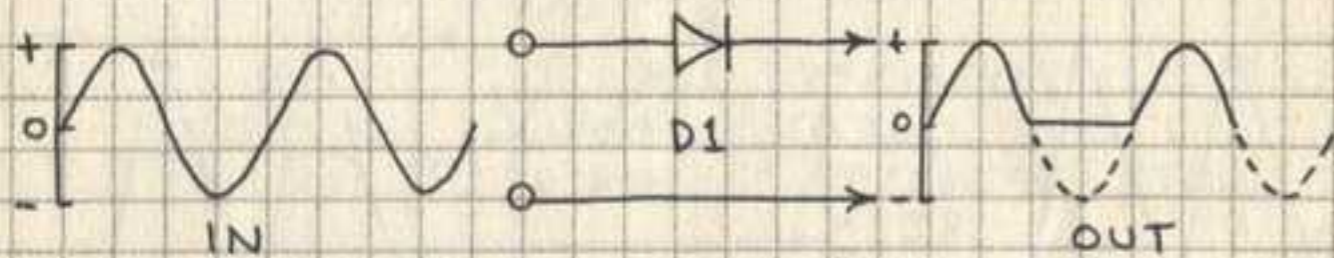
D1 IS ANY DIODE RATED FOR THE INPUT VOLTAGE.
THIS CIRCUIT IS USED TO TRANSFORM AN AC
WAVE INTO PULSATING DC AND TO DETECT
MODULATED RADIO SIGNALS.

DUAL HALF-WAVE RECTIFIER
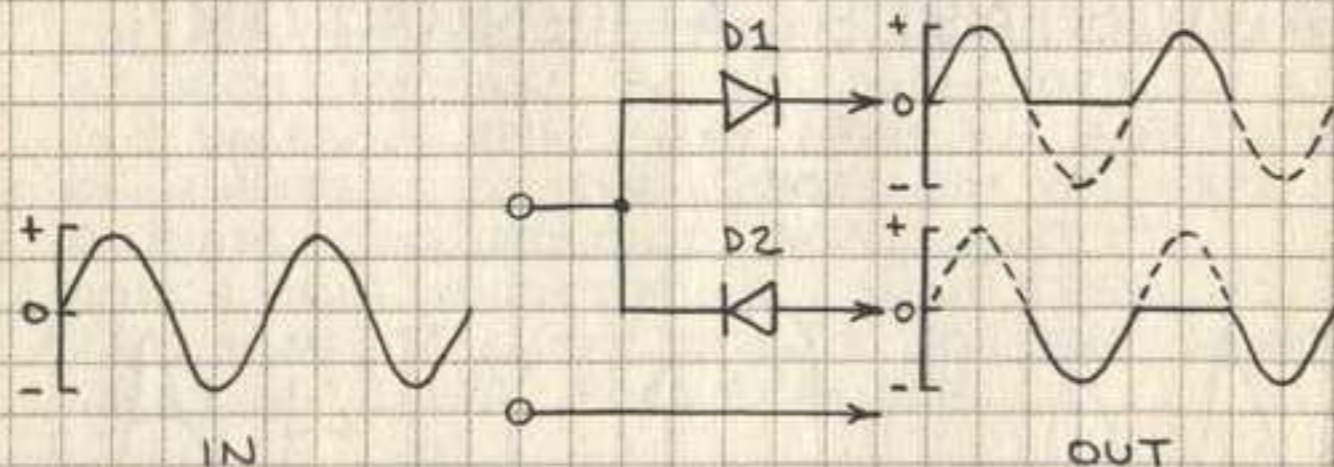
THIS CIRCUIT TRANSFORMS BOTH HALVES OF
AN AC WAVE INTO PULSATING DC.

FULL-WAVE RECTIFIER

D1-D4 AVAILABLE AS MODULE.
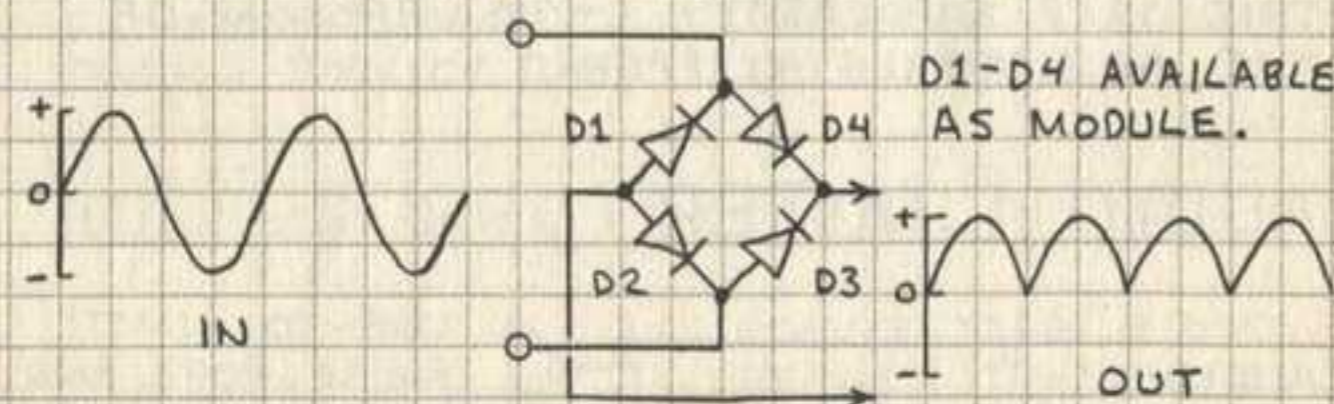
ALSO CALLED A BRIDGE RECTIFIER. USED TO
TRANSFORM BOTH HALVES OF AC WAVE TO DC.

18

CASCADE VOLTAGE DOUBLER
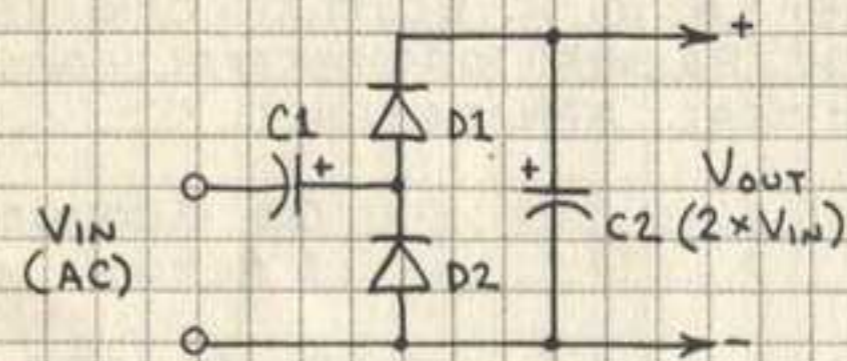
COMPONENTS
SHOULD BE
RATED AT
$2 \times V_{IN}$. USE
LARGE VALUE
CAPACITORS TO
REDUCE RIPPLE.

BRIDGE VOLTAGE DOUBLER
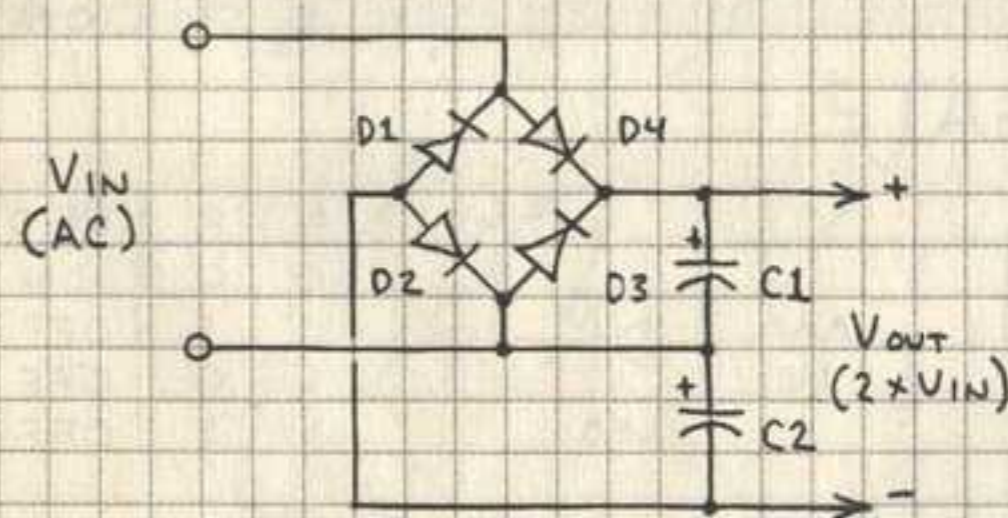
COMPONENTS
SHOULD BE
RATED AT
$2 \times V_{IN}$.
OK TO
USE BRIDGE
MODULE
FOR D1, D2,
D3 AND D4.

VOLTAGE QUADRUPLER
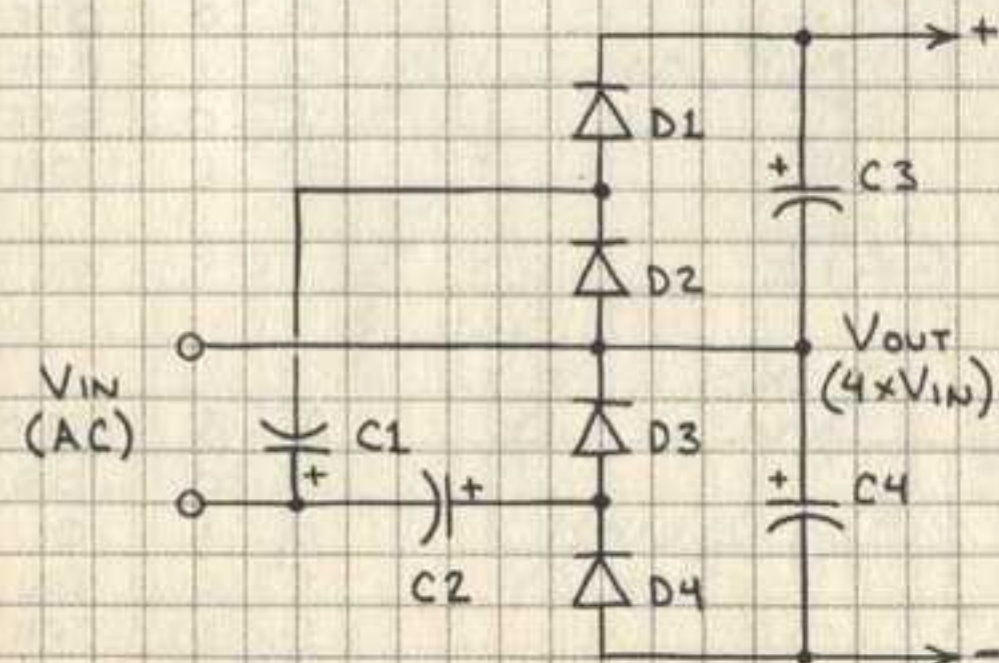
COMPONENTS
SHOULD BE
RATED AT
$2 \times V_{IN}$.
USE LARGE
VALUE
CAPACITORS
TO REDUCE
RIPPLE.

CAUTION: VOLTAGE MULTIPLICATION CIRCUITS
CAN PRODUCE HIGH VOLTAGES. USE CARE!

19

DIODE LOGIC GATES

THESE SIMPLE LOGIC CIRCUITS CAN BE
USED TO TEACH BASICS OF DIGITAL LOGIC
AND IN PRACTICAL APPLICATIONS.
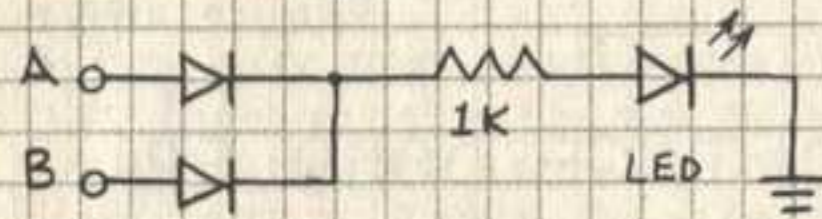
O = GROUND
1 = +6V

OR GATE

A	B	LED
O	O	OFF
O	1	ON
1	O	ON
1	1	ON

NOR GATE
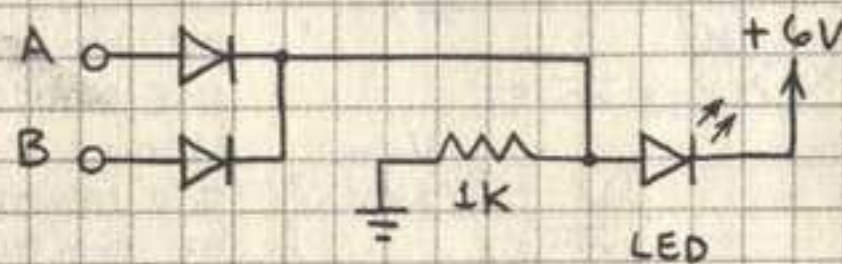
A	B	LED
O	O	ON
O	1	OFF
1	O	OFF
1	1	OFF
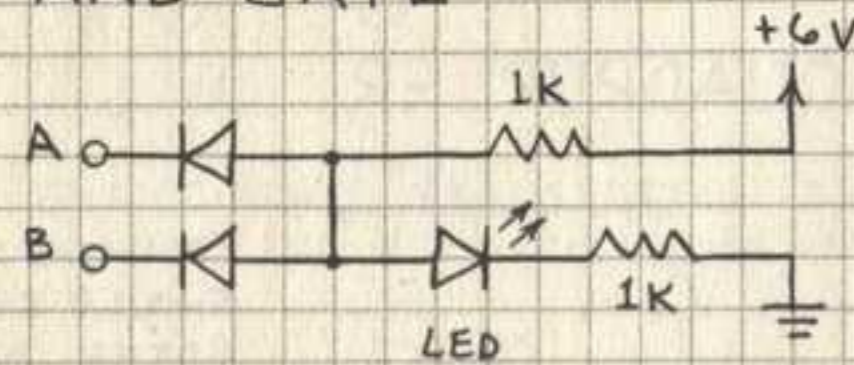
AND GATE

A	B	LED
O	O	OFF
O	1	OFF
1	O	OFF
1	1	ON

NAND GATE
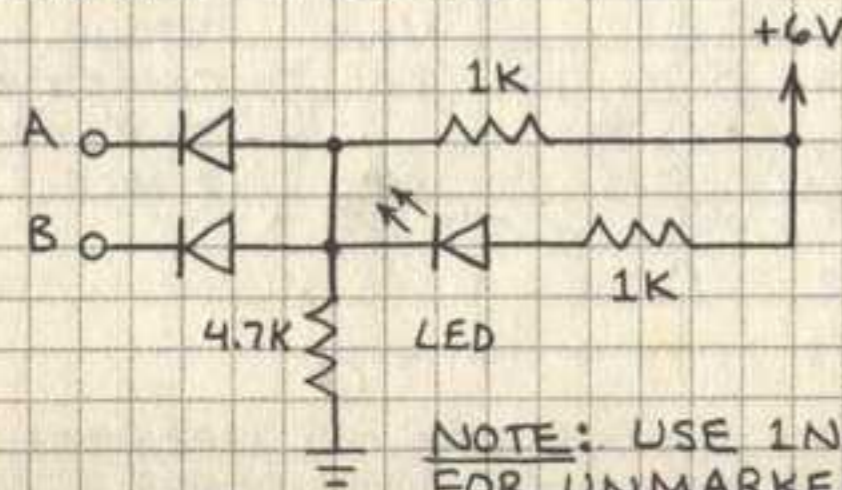
A	B	LED
O	O	ON
O	1	ON
1	O	ON
1	1	OFF

NOTE: USE 1N914 (OR SIMILAR)
FOR UNMARKED INPUT DIODES.

20

DECIMAL-TO-BINARY ENCODER

THIS CIRCUIT IS A PROGRAMMABLE READ-
ONLY MEMORY (PROM). USE 1N914 DIODES.

BINARY TRUTH TABLE

DECIMAL INPUT SWITCHES
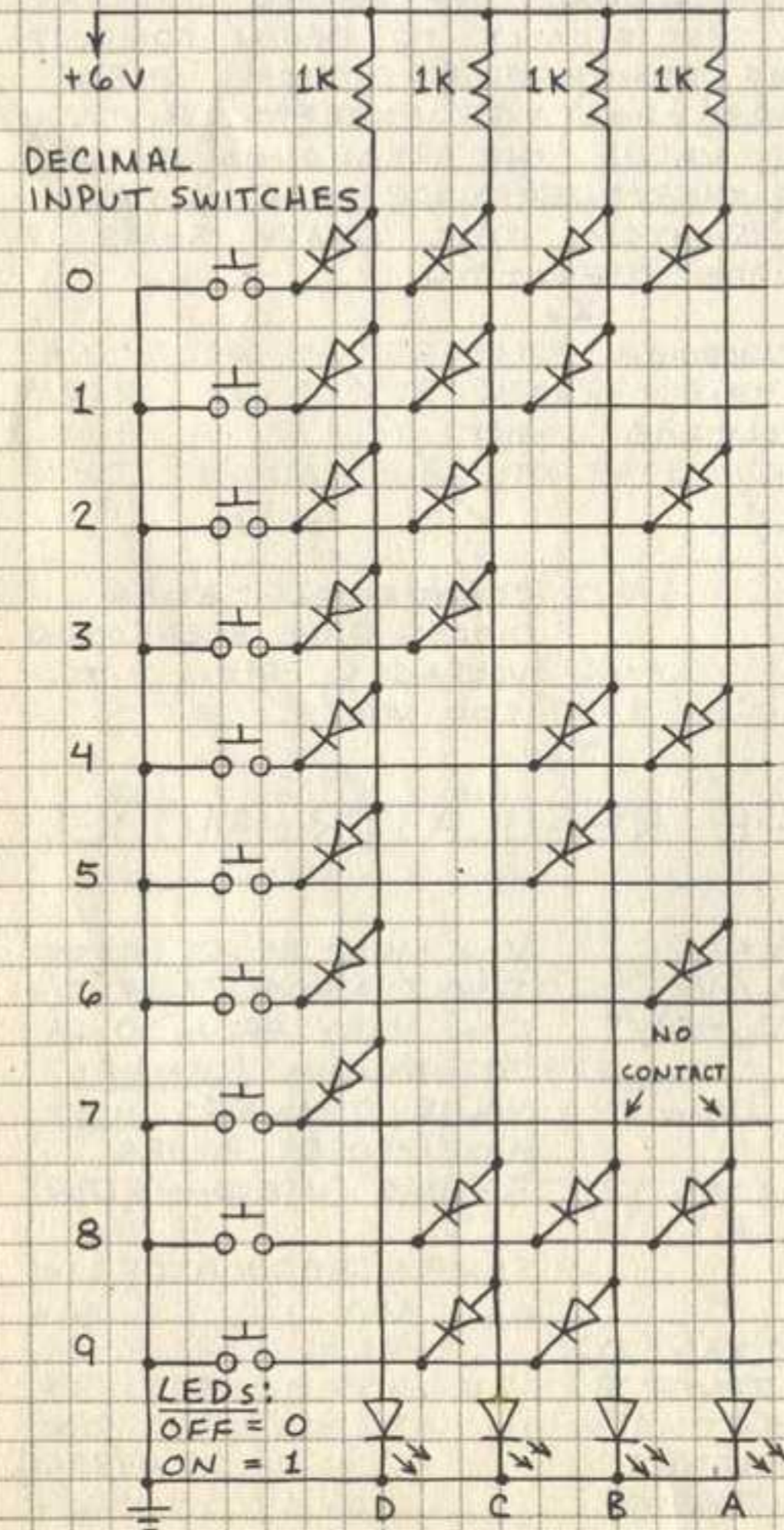
Decimal	D C B A
0	0 0 0 0
1	0 0 0 1
2	0 0 1 0
3	0 0 1 1
4	0 1 0 0
5	0 1 0 1
6	0 1 1 0
7	0 1 1 1
8	1 0 0 0
9	1 0 0 1

NO CONTACT

LEDs:
OFF = 0
ON = 1

D C B A

BINARY READOUT LEDs

21

ZENER DIODES

NORMALLY A CURRENT DOES NOT FLOW THROUGH A DIODE CONNECTED IN THE REVERSE DIRECTION. THE ZENER DIODE IS DESIGNED SPECIFICALLY TO BEGIN CONDUCTING IN THE REVERSE DIRECTION WHEN THE REVERSE VOLTAGE EXCEEDS A THRESHOLD VALUE (THE BREAKDOWN VOLTAGE). THEREFORE THE ZENER DIODE IS A VOLTAGE-SENSITIVE SWITCH. THIS GRAPH SUMS UP ZENER DIODE OPERATION:

COMMERCIAL ZENER DIODES HAVE BREAKDOWN VOLTAGES FROM 2 TO 200 VOLTS.
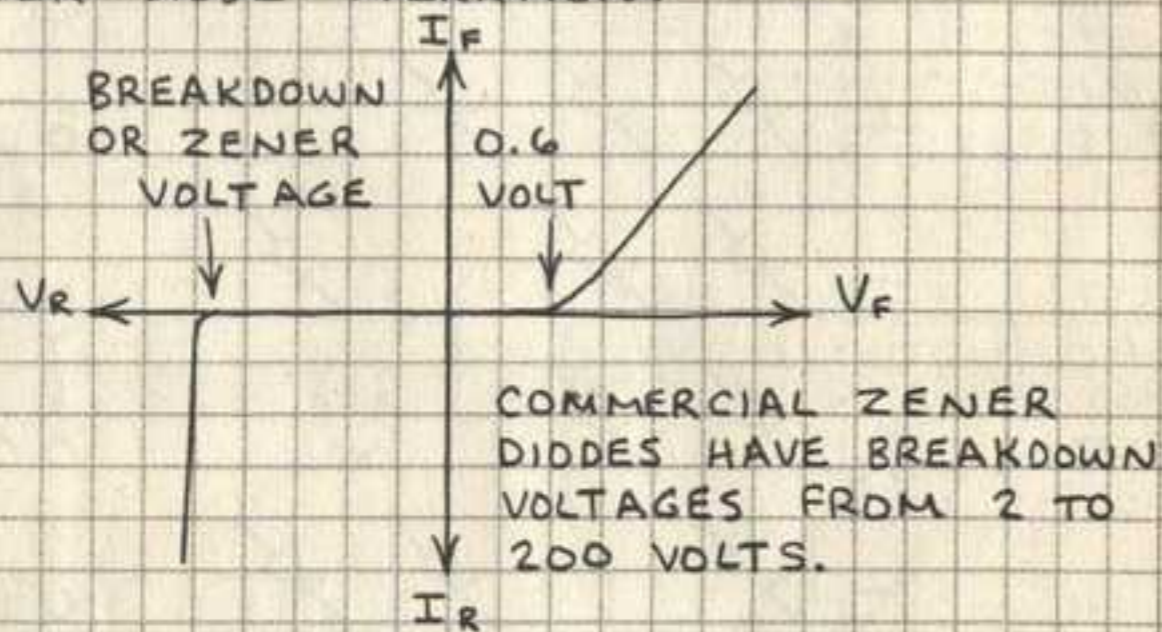
VOLTAGE REGULATOR MODEL

$P_Z = V_Z \times I_L$
$I_Z = P_Z / V_Z$
$R1 = (V_{IN} - V_Z)/I$
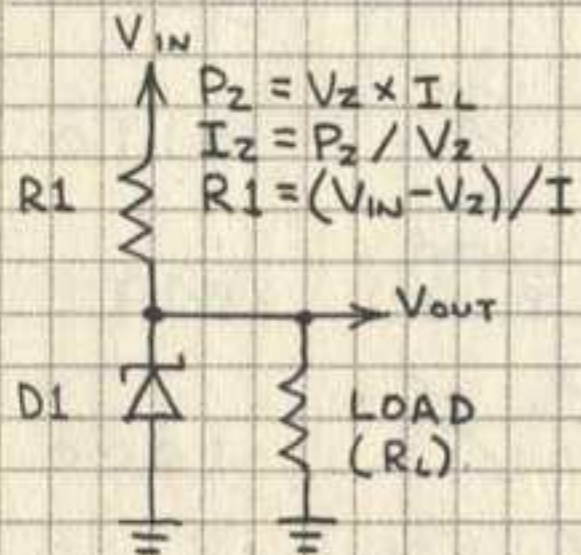
V_{IN} MUST BE AT LEAST 1 VOLT ABOVE V_{OUT}. I_L CAN VARY FROM 0 mA TO MAXIMUM PLANNED VALUE. D1 AND R1 MUST HAVE PROPER POWER RATING (USE OHM'S LAW).

SAMPLE REGULATOR:

12V	60Ω	D1	9V
IN	1/2 W	OUT	
		1/2W (50mA)	

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

22

VOLTAGE INDICATOR

	R1	R2	R3	R4	R5
	330	470	680	1K	1.2K

INPUT VOLTAGE (0-15V)

	D1	D2	D3	D4	D5
	5V	6V	9V	12V	15V
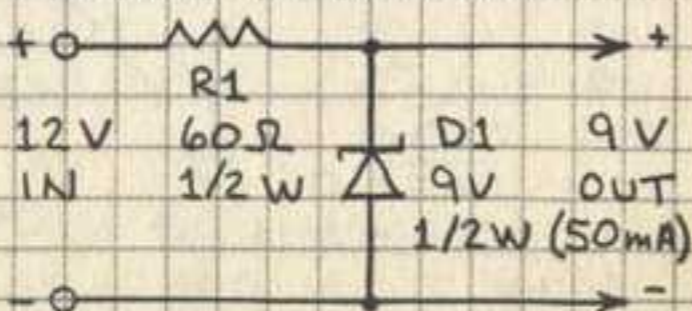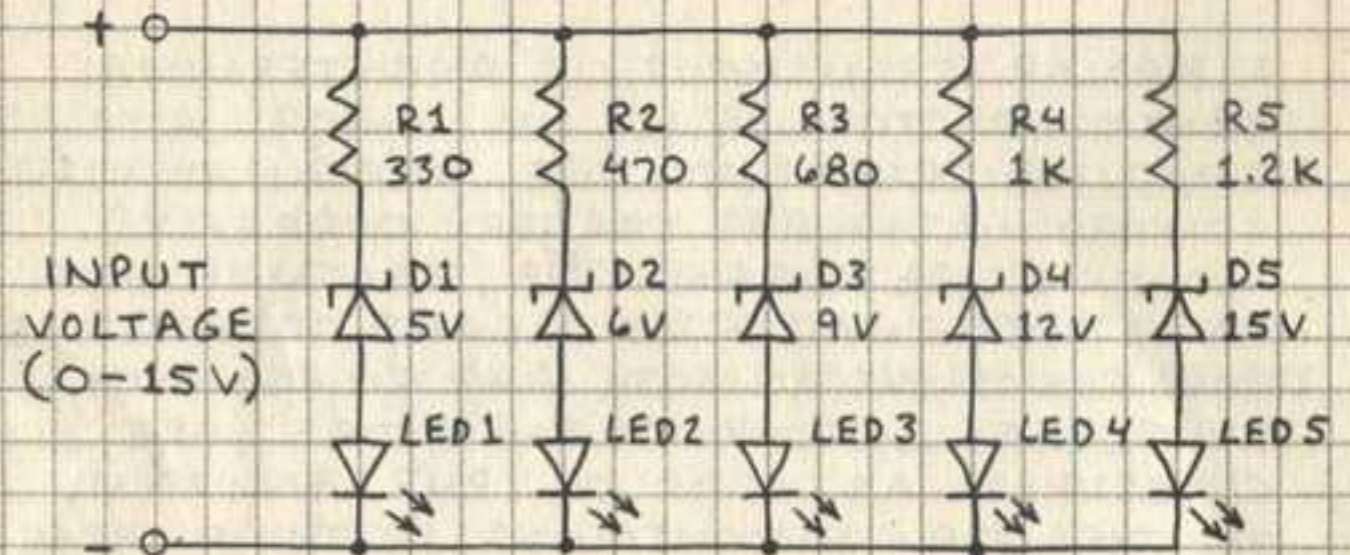
LEDs GLOW IN SEQUENCE AS INPUT VOLTAGE RISES. OK TO USE DIFFERENT ZENERS SO LONG AS SERIES RESISTOR LIMITS CURRENT THROUGH LED TO SAFE VALUE.

VOLTAGE SHIFTER
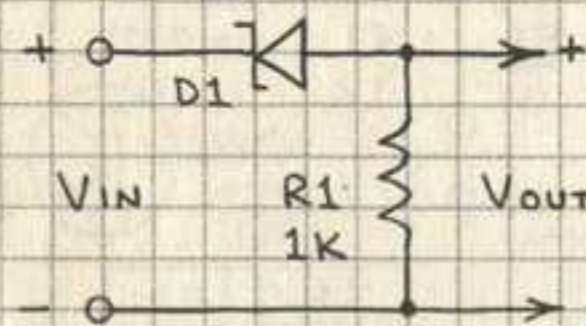
EXAMPLE (D1=6.2V):

V_{IN}	V_{OUT}
5	0
6	.36
9	3.17
12	6.37
15	9.27

WAVEFORM CLIPPERS

R1: SEE P.22
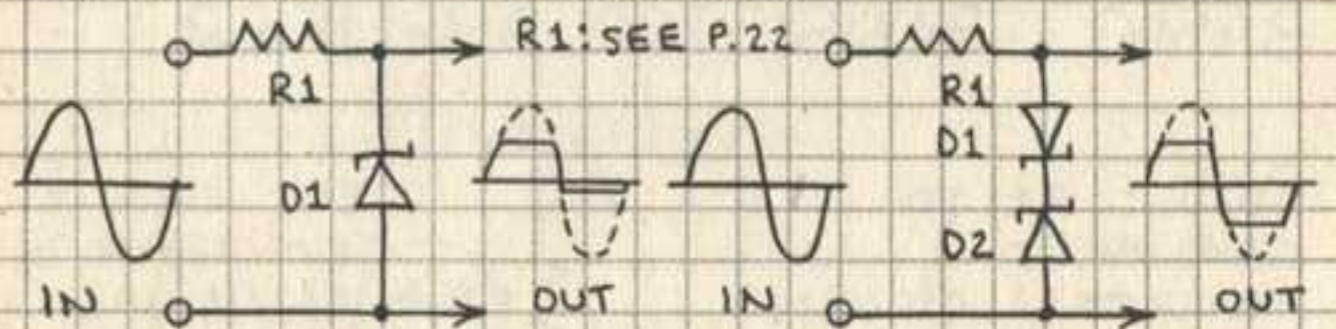
USE TO REDUCE LEVEL OF INCOMING SIGNAL. ALSO CONVERTS SINE WAVE TO NEAR SQUARE WAVE.

CLIPS BOTH HALVES OF WAVE (EQUALLY WHEN D1=D2). USE AS POP FILTER FOR SPEAKERS AND PHONES.

23

BIPOLAR TRANSISTORS

A BIPOLAR TRANSISTOR IS A 3-TERMINAL
SEMICONDUCTOR DEVICE IN WHICH A
SMALL CURRENT AT ONE TERMINAL CAN
CONTROL A MUCH LARGER CURRENT
FLOWING BETWEEN THE SECOND AND
THIRD TERMINAL. THIS MEANS TRANSISTORS
CAN FUNCTION AS BOTH AMPLIFIERS AND
SWITCHES. BIPOLAR TRANSISTORS ARE
CLASSIFIED AS NPN OR PNP ACCORDING
TO THE DOPING CONTAINED IN THEIR THREE
REGIONS.

BASIC TRANSISTOR SWITCHES

S1	LED
LO	OFF
HI	ON

S1	LED
LO	ON
HI	OFF
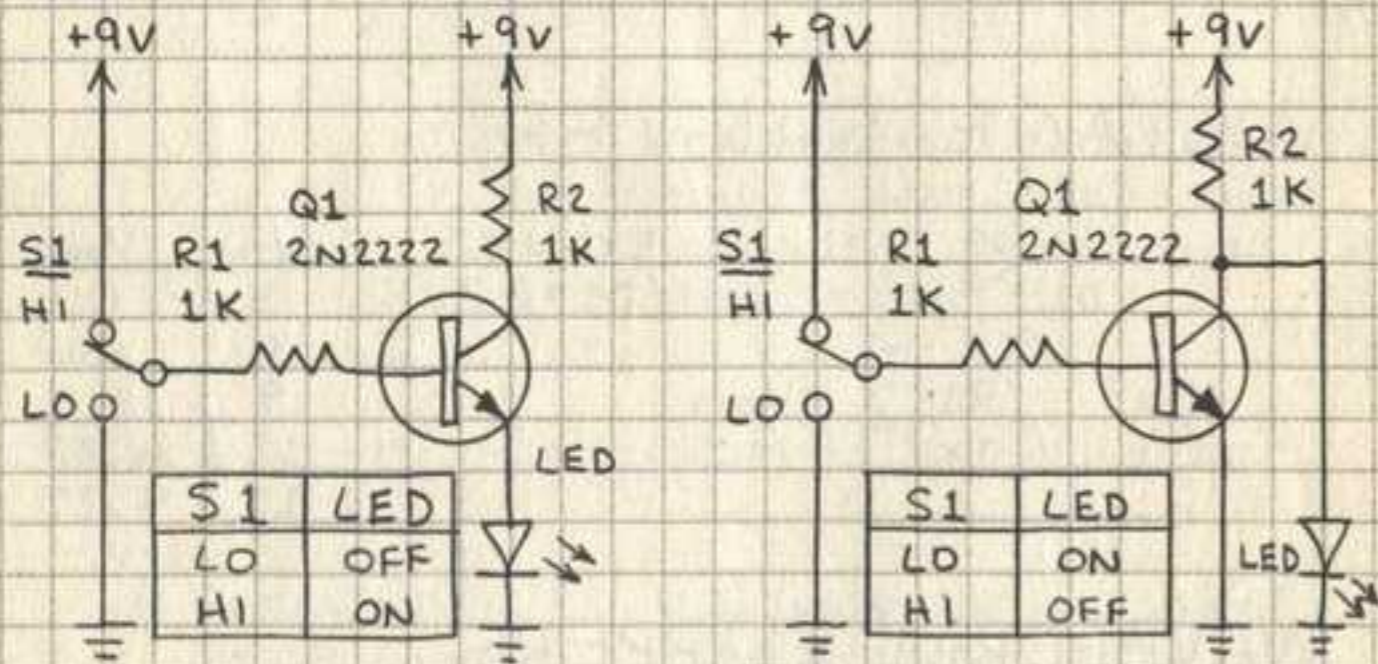
BASIC TRANSISTOR AMPLIFIER

ADJUST R1 TO
GIVE BEST
RESULTS.

TEST CIRCUIT
GAVE GAIN
$(V_{OUT}/V_{IN}) = 50$.

24

RELAY DRIVER

RELAY
275-004

RELAY PULLS IN WHEN
INPUT IS POSITIVE.
APPLICATION:

RESISTIVE SENSOR OR
MOISTURE-SENSING PROBES

RELAY CONTROLLER

RELAY
275-004

SUPPLIES SEQUENCE
OF DRIVE PULSES
TO RELAY. R1 AND
C1 CONTROL PULSE
RATE AND TIME
RELAY IS CLOSED
PER PULSE. R4
CONTROLS PULSE
RATE. USE TO
FLASH LAMPS AND
CONTROL MOTORS.

LED REGULATOR

SUPPLIES
CONSTANT
CURRENT
TO LED AS
SUPPLY
VOLTAGE
CHANGES.

LED CURRENT = $7 \to 8$ mA. LED

25

3-VOLT SPEAKER AMPLIFIER

USE TO GIVE
LOW-POWER
SPEAKER TO
RADIOS AND TAPE
PLAYERS WITHOUT
SPEAKERS.

+3V

T2   8Ω
      SPKR

+ C2
.1µF

R1
15K

T1

+)|(

C1
4.7µF

8Ω
INPUT

8Ω   1K

Q1
2N2222

1K   8Ω

R2   R3   + C3
10K   100   47µF

2-STAGE SPEAKER AMPLIFIER

THIS CIRCUIT REQUIRES NO
INPUT TRANSFORMER.

+3V

T1   8Ω
      SPKR

R1   R3   R7   C4
15K   1K   15K   .1µF

C1   C3
4.7µF   4.7µF

+)|(+)|(

INPUT

Q1   Q2
2N2222   2N2222

1K   8Ω

R2   R4   C2 +   R8   R9   C5 +
15K   100   47µF   15K   100   47µF

USE TO GIVE LOW-POWER SPEAKER TO
RADIOS AND TAPE PLAYERS WITHOUT SPEAKERS.

26

MICROPHONE PREAMPLIFIER

+9V

RED

R1   Q1   R5
15K   2N2222   10K

)|(→

ELECTRET   C1   C2
MIC   .1µF   .1µF   TO
ELEMENT   AMPLIFIER

        R2   R4   + C3
        1K   1K   1µF
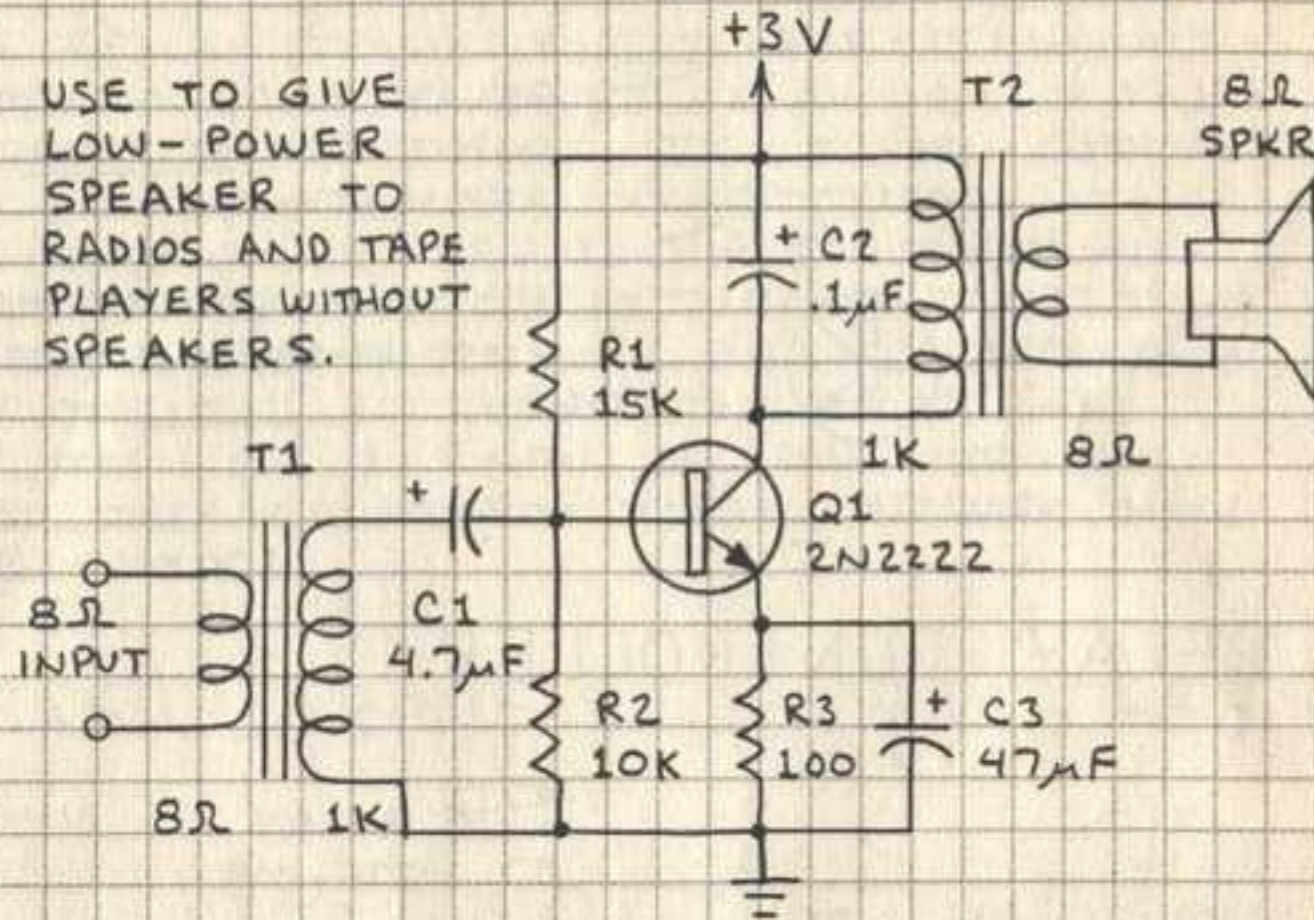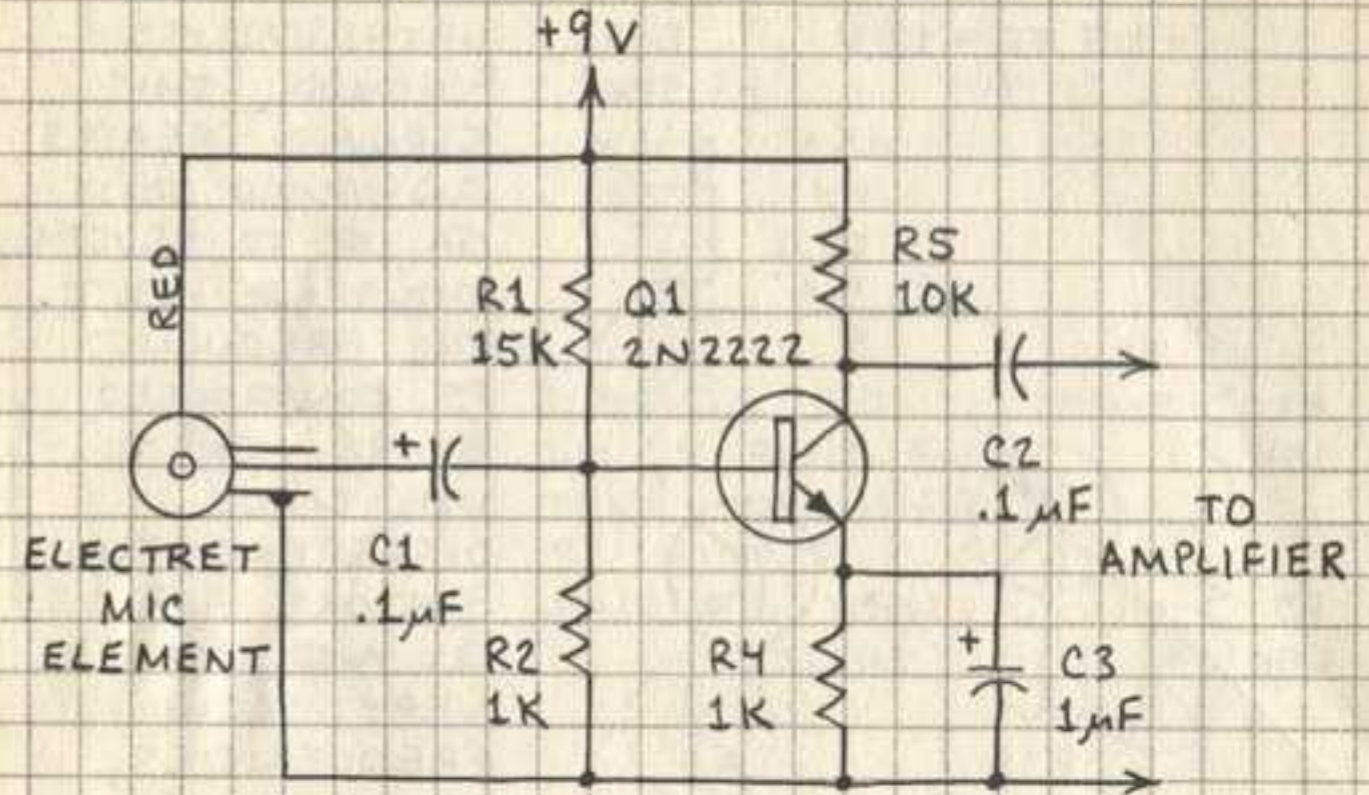
USE WITH TAPE RECORDERS, PUBLIC ADDRESS
SYSTEMS AND PORTABLE AMPLIFIERS.

AUDIO MIXER

C1   INPUTS: +9V   OK TO ADD
.1µF A, B   MORE INPUT
A o—+)|(NETWORKS
        R3   (C1, R1, R3).
        10K

R1   R7   C3
100K   15K   .1µF
                RS 10K
C2   )|(→
.1µF

B o—+)|(Q1   TO
        R4   2N2222   AMPLIFIER
        10K

R2   R6   R8   + C4
100K   1K   1K   1µF
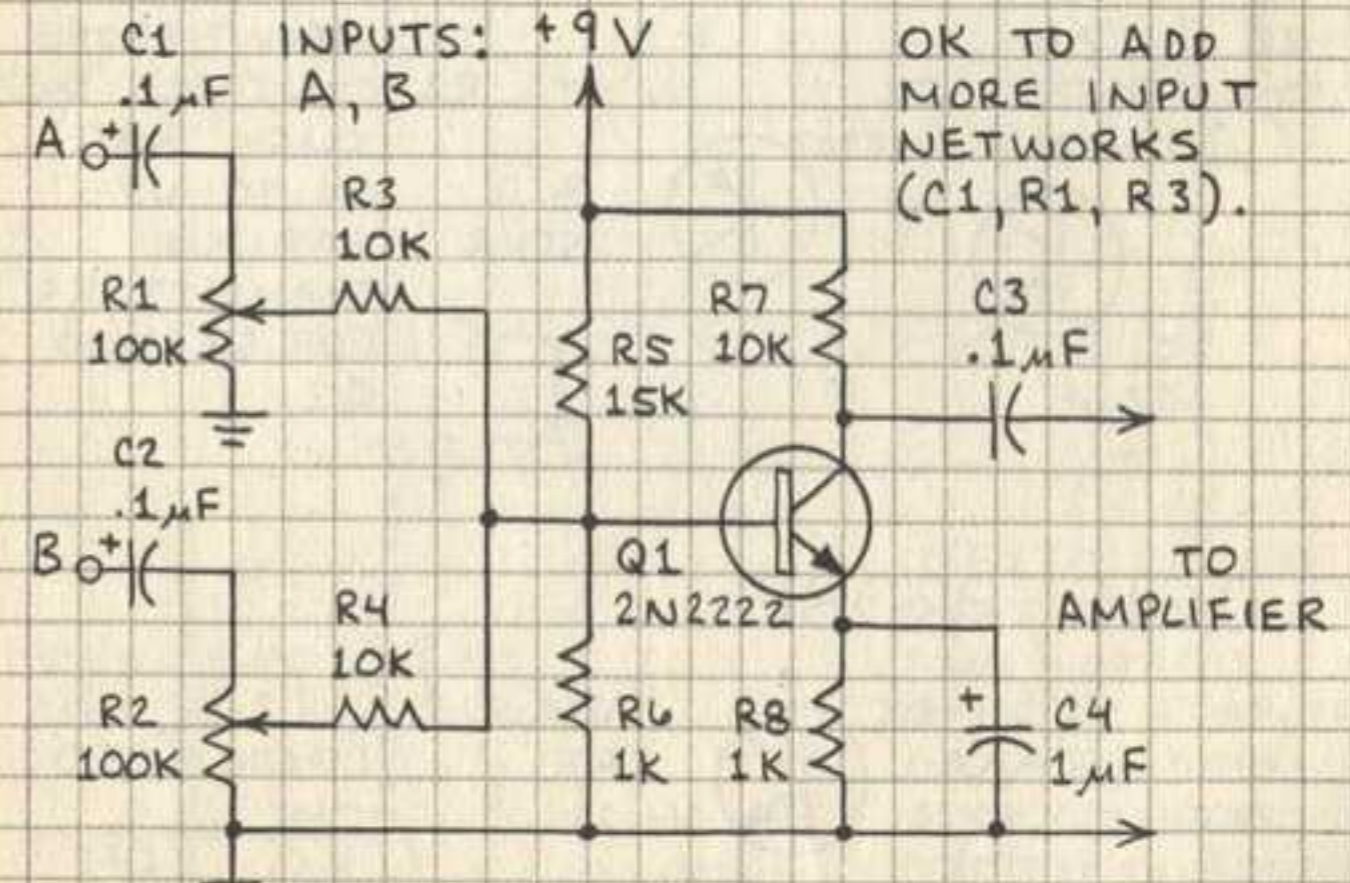
USE TO COMBINE SIGNALS FROM TWO
(OR MORE) AMPLIFIERS, MICROPHONES, ETC.

27

AUDIO OSCILLATOR

+1.5 TO +12 V

8 Ω SPKR

R4 10Ω

Q1 2N2907

R1 10K

C1 .01 μF

R2 68K

Q2 2N2222

R3 50K
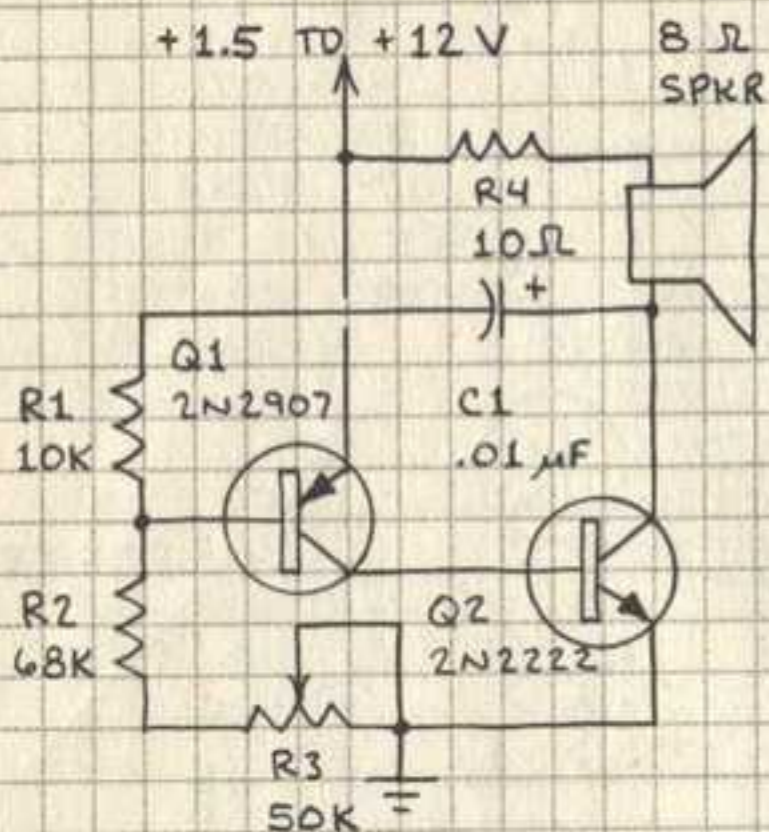
WITH VALUES SHOWN, THIS CIRCUIT CREATES AN AUDIO TONE OF UP TO SEVERAL THOUSAND HERTZ. THE FREQUENCY IS CONTROLLED BY R3. OK TO USE MANY DIFFERENT TRANSISTORS FOR Q1 AND Q2. FOR VERY SLOW FREQUENCIES, INCREASE C1.

METRONOME

R1 10K

+9V

R2 50K

Q1 2N2222

Q2 2N2907

8 Ω SPKR

C1 22 μF
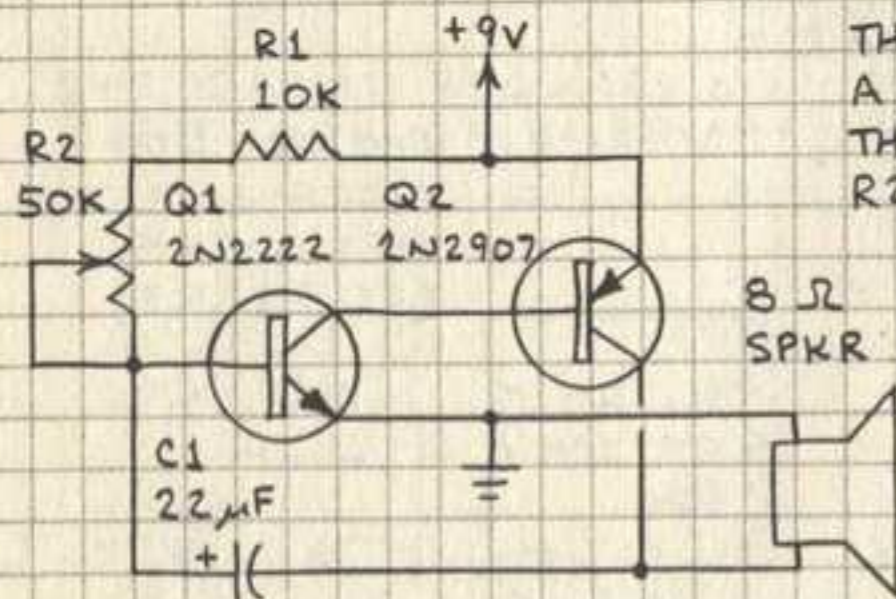
THIS CIRCUIT IS A VARIATION OF THE CIRCUIT ABOVE. R2 CONTROLS THE "CLICK" RATE. OK TO USE VARIOUS TRANSISTORS FOR Q1 AND Q2.

LOGIC PROBE

TO LOGIC CIRCUIT

Q1

R2 1K

+5V

R1 10K

LED

Q1 2N2222

LOGIC IN	LED
LO	OFF
HI	ON

ADJUSTABLE SIREN

R1 22K

S1

+3 TO +9V

C1 22 μF

R3 15K

R2 39K

R4 50K
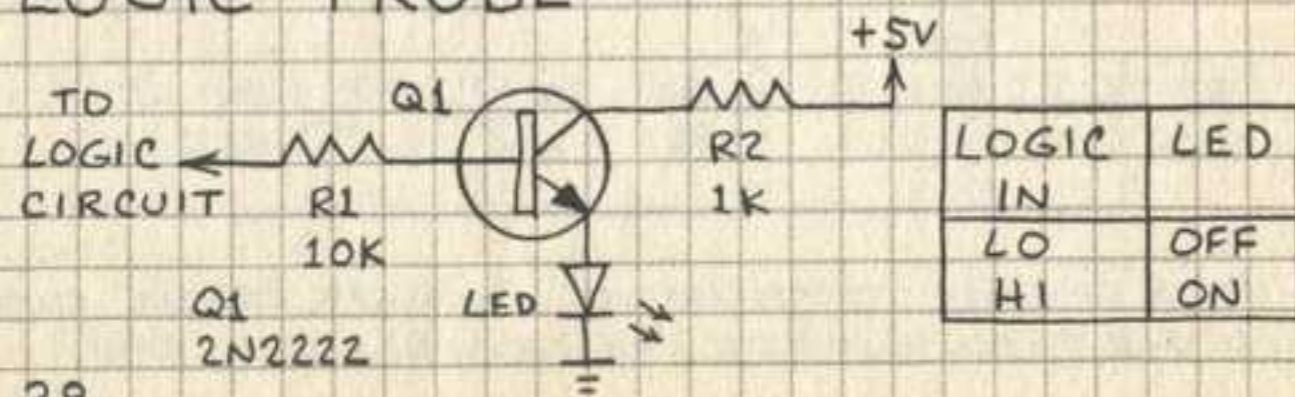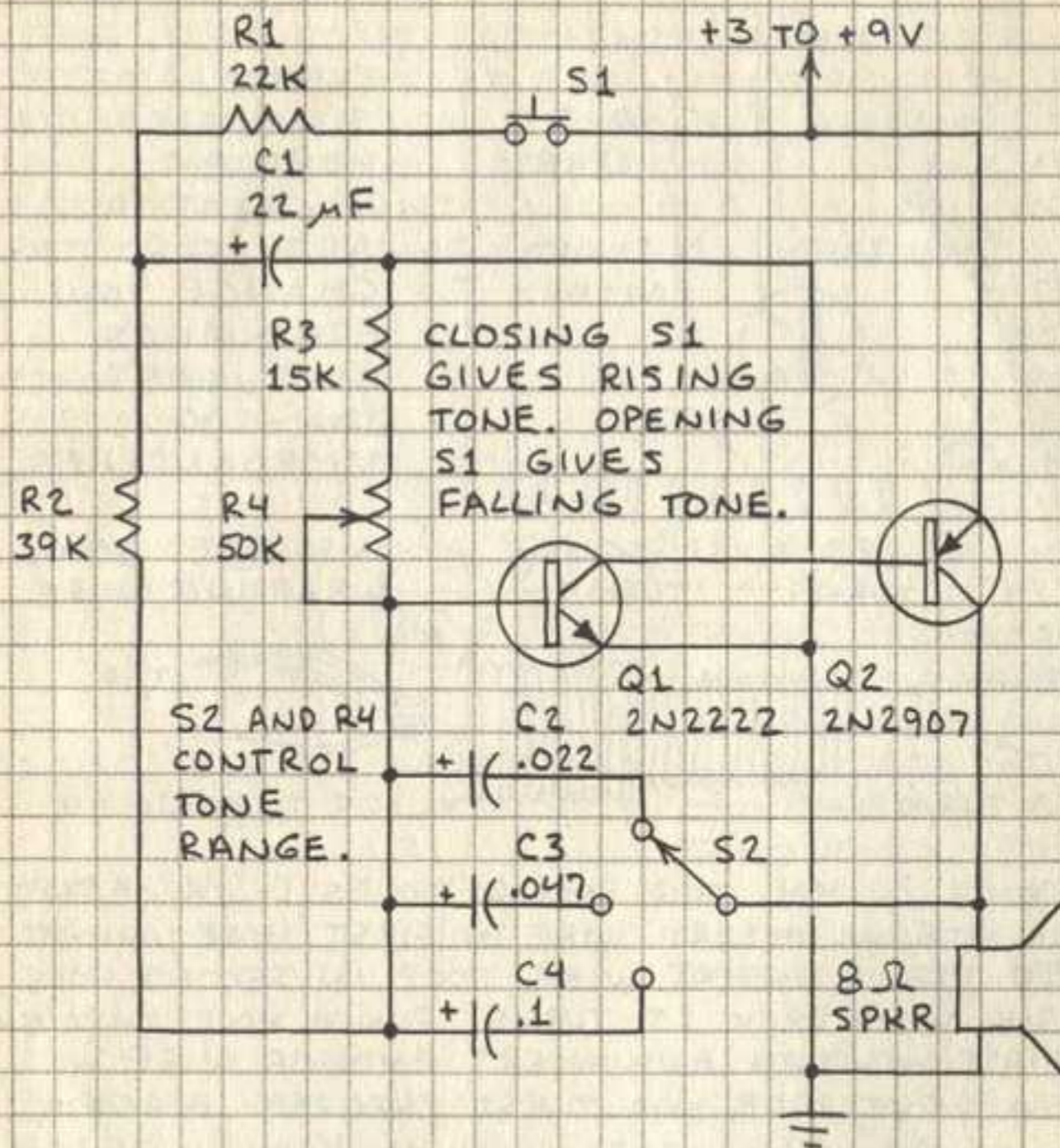
CLOSING S1 GIVES RISING TONE. OPENING S1 GIVES FALLING TONE.

Q1 2N2222

Q2 2N2907

S2 AND R4 CONTROL TONE RANGE.

C2 .022

C3 .047

S2

C4 .1

8 Ω SPKR

AUDIO NOISE GENERATOR

+6 TO +12 V

R1 100K

R2 1K

C1 .1 μF

Q1 2N2222

NOISE OUT (TO AMPLIFIER)
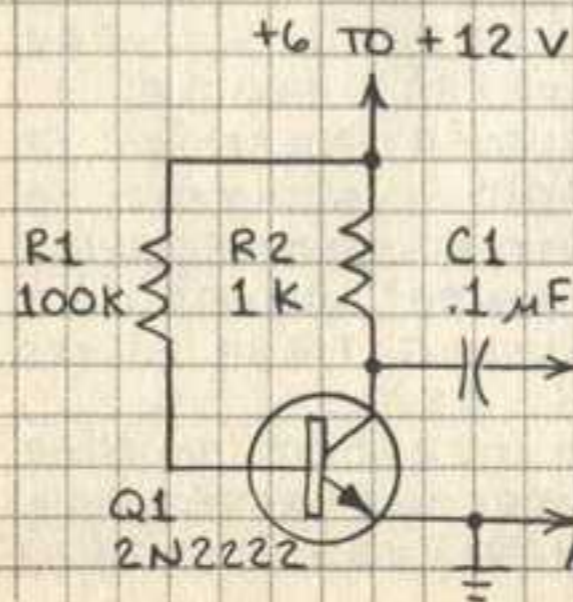
USE TO CREATE FUZZ SOUND AND OTHER SPECIAL EFFECTS OR AS NOISE SOURCE FOR TESTING ROOM ACOUSTICS WITH SOUND METER.

1-TRANSISTOR OSCILLATOR
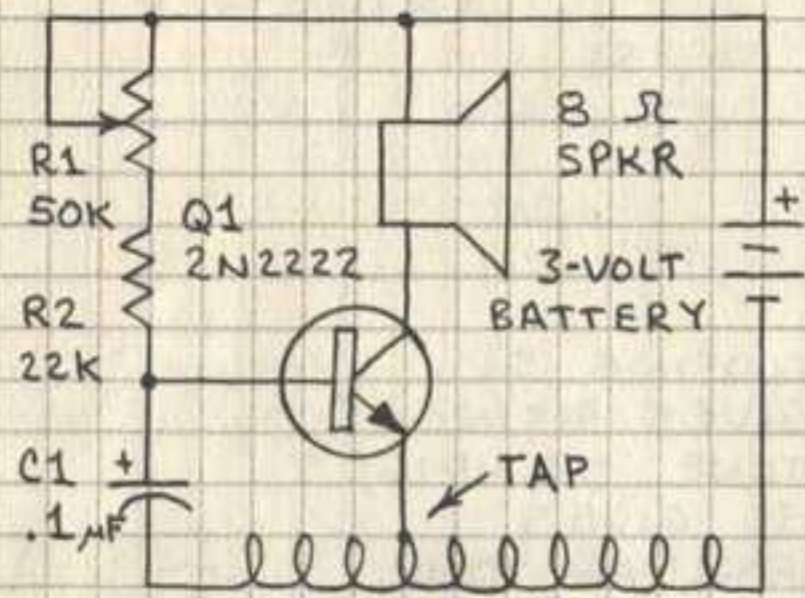
THIS IS A SIMPLIFIED HARTLEY OSCILLATOR. ADJUST R1 TO CHANGE TONE FREQUENCY. CONSUMES ONLY 100 - 200 MICROAMPERES.

8 Ω SPKR
3-VOLT BATTERY
R1 50K
Q1 2N2222
R2 22K
C1 .1 μF
TAP
25 TURNS
50 TURNS
INSULATED 30 GA. WRAPPING WIRE

1/4" SODA STRAW →
50 TURNS →
25 TURNS
TAP
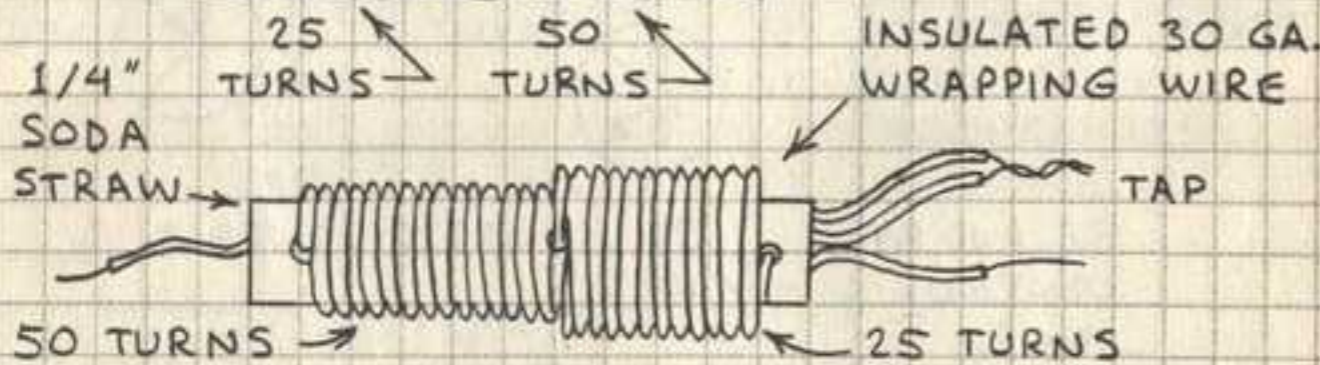
COIL: PUNCH TWO SMALL HOLES 1-1/8" APART IN STRAW. INSERT WIRE IN FIRST HOLE, WIND 50 TURNS, INSERT WIRE LOOP IN SECOND HOLE, AND WIND BACK 25 TURNS. PUNCH HOLE THROUGH FIRST WINDING AND INSERT END OF WIRE. TAP: CUT LOOP AND TWIST EXPOSED WIRES.

SWITCH DEBOUNCER

+3 TO +15 V

Q1 2N2222
R1 10K
R2 4.7K
OUT
C1 1 μF
S1
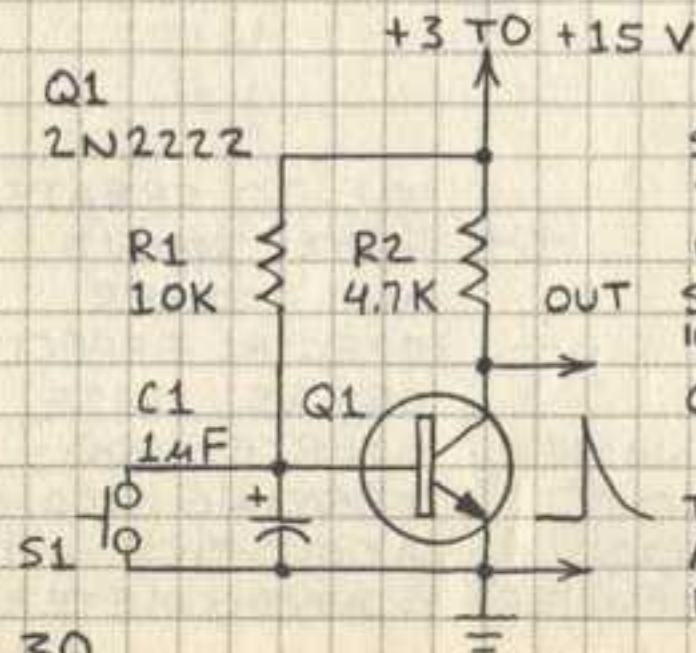
SUPPLIES SINGLE TRIGGER PULSE TO LOGIC CIRCUITS. SWITCH ALONE WILL "BOUNCE" WHEN CLOSED, CAUSING FALSE PULSES.

TO LOCK OUT S1 FOR A SECOND AFTER A PULSE, LET C1 = 220 μF.

30

MINIATURE RF TRANSMITTER

THIS CIRCUIT IS PATTERNED AFTER A PILL-SIZED BIOTELEMETRY TRANSMITTER FIRST DEVELOPED BY DR. R. STEWART MACKAY AND OTHER MEDICAL RESEARCHERS IN THE LATE 1950's. THIS TRANSMITTER REMAINS ONE OF THE SMALLEST EVER DEVELOPED.

12" ANTENNA (OPTIONAL)
C1 .1 - 10 μF
R1 50K
R2 22K
25 TURNS
50 TURNS
TAP Q1 2N2222
B1 1-1/2 V
USES ONLY 100 μA.

SIGNAL AT Q1's BASE:

RF HARMONICS
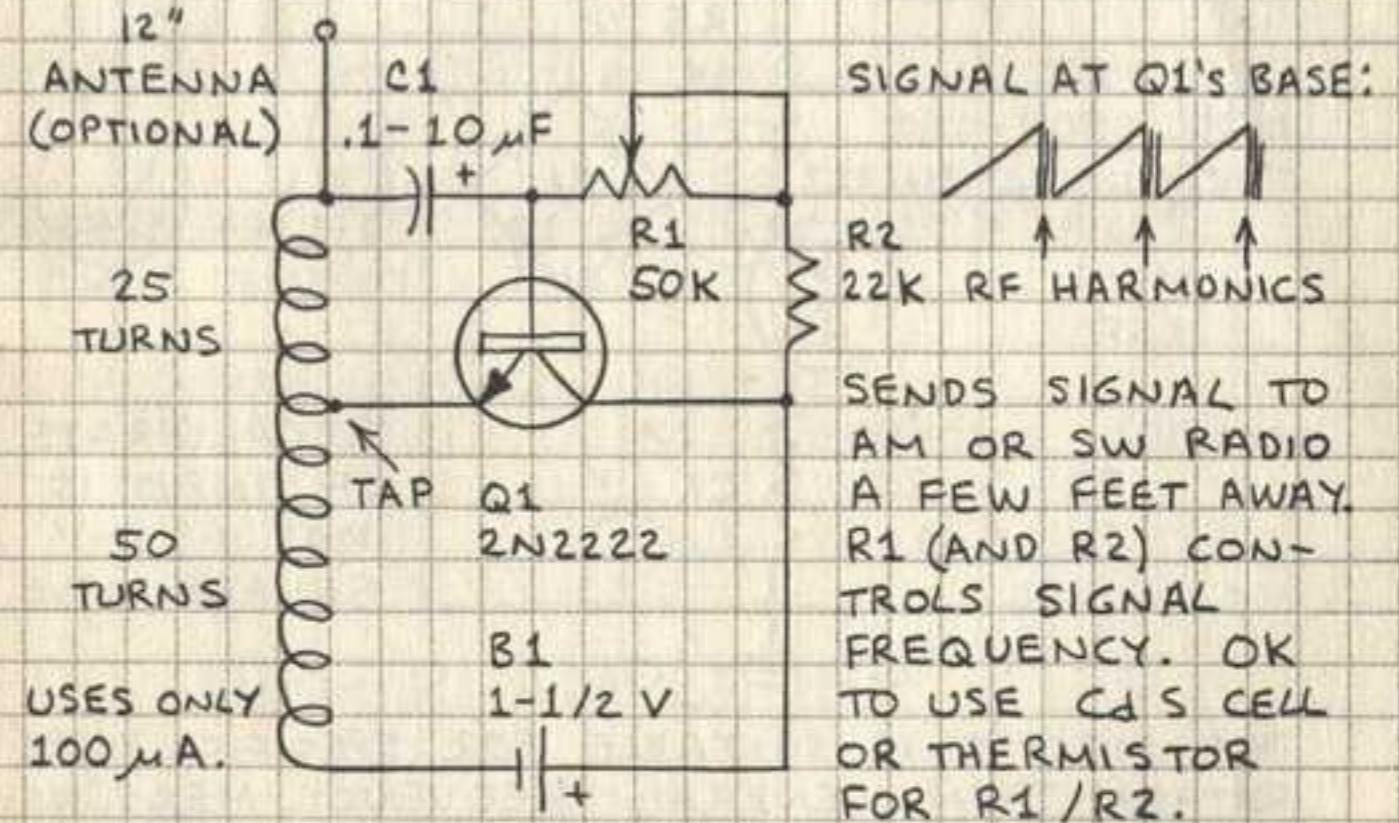
SENDS SIGNAL TO AM OR SW RADIO A FEW FEET AWAY. R1 (AND R2) CONTROLS SIGNAL FREQUENCY. OK TO USE CdS CELL OR THERMISTOR FOR R1/R2.

COIL: USE THE COIL SHOWN ON THE FACING PAGE OR MAKE A MUCH SMALLER VERSION WITH A 1/2" LENGTH OF SODA STRAW AND NO. 30 MAGNET WIRE. BURN THE VARNISH FROM THE LAST 1/4" OF THE COIL'S LEADS (USE A MATCH). THEN LIGHTLY BUFF THE CHARRED VARNISH WITH FINE SAND PAPER.

B1: USE A PENLIGHT CELL OR A MERCURY OR SILVER OXIDE BUTTON CELL. WARNING: NEVER ATTEMPT TO SOLDER LEADS TO MINIATURE POWER CELLS. THEY WILL EXPLODE.

C1: 0.1 μF GIVES AUDIO TONE; 10 μF GIVES AUDIBLE CLICKS. INSERT FERRITE CORE OR STEEL NAIL IN COIL TO ALTER THE SIGNAL. USE MINIATURE ELECTROLYTIC CAPACITOR.

31

FREQUENCY METER

INPUT IS
1-VOLT
SQUARE
WAVE.

R1
1K

IN

R2
50K

C1
.1µF

R4
100

R5
1K

Q1
2N2222

B1 — USE RECTIFIER
BRIDGE MODULE OR
FOUR 1N914 DIODES.

B1

M1
0-1mA

R3
1K

R6
100

C2
.1µF

RECALIBRATE
IF INPUT IS
NOT A 1-V
SQUARE WAVE.

+6V
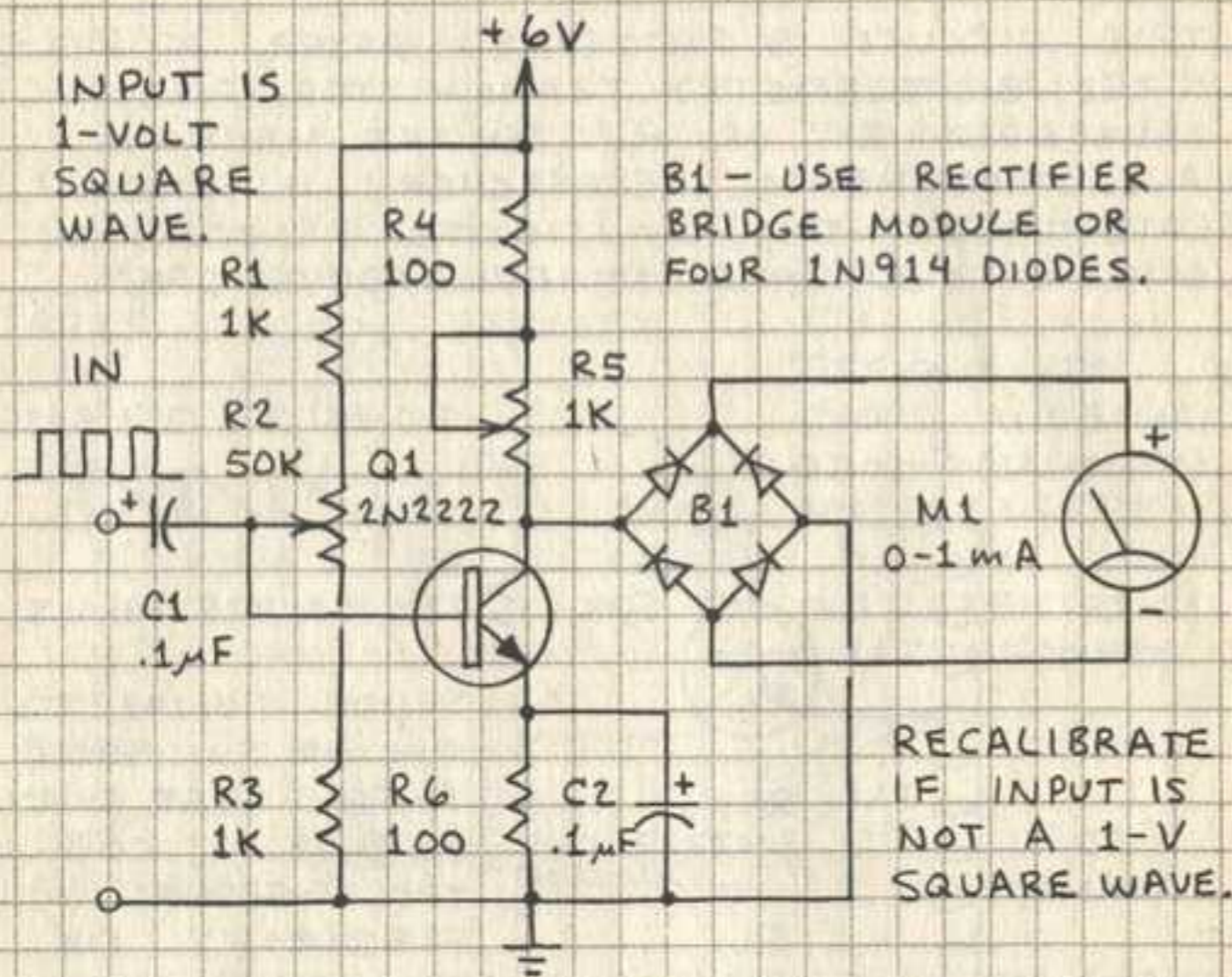
THIS CIRCUIT IS SUITABLE FOR SPECIFIC ROLES
RATHER THAN GENERAL FREQUENCY MEASURE-
MENTS. TO CALIBRATE FOR 0-1 KHz RANGE:

1. SET R2 AND R5
AT MID POINTS.
2. APPLY 1 KHz, 1 VOLT
SQUARE WAVE AT
INPUT.
3. ADJUST R2
UNTIL M1 = 1mA.
4. REMOVE 1 KHz
SIGNAL.
5. ADJUST R3
UNTIL M1 = 0.
6. REAPPLY 1 KHz
SIGNAL.
7. ADJUST R2
UNTIL M1 = 1mA.

TYPICAL RESULTS:

SIGNAL (Hz)	M1 (mA)
0	.02
100	.1
200	.24
300	.34
400	.44
500	.55
600	.65
700	.77
800	.85
900	.95
1000	1.00

PULSE GENERATOR

+3 TO +15 V

R3 CONTROLS
PULSE RATE.

D1
1N914

R1
470

C1
.001 TO .1µF

R2
1M

Q1
2N2907

Q2
2N2222

R3
1M

R4
50
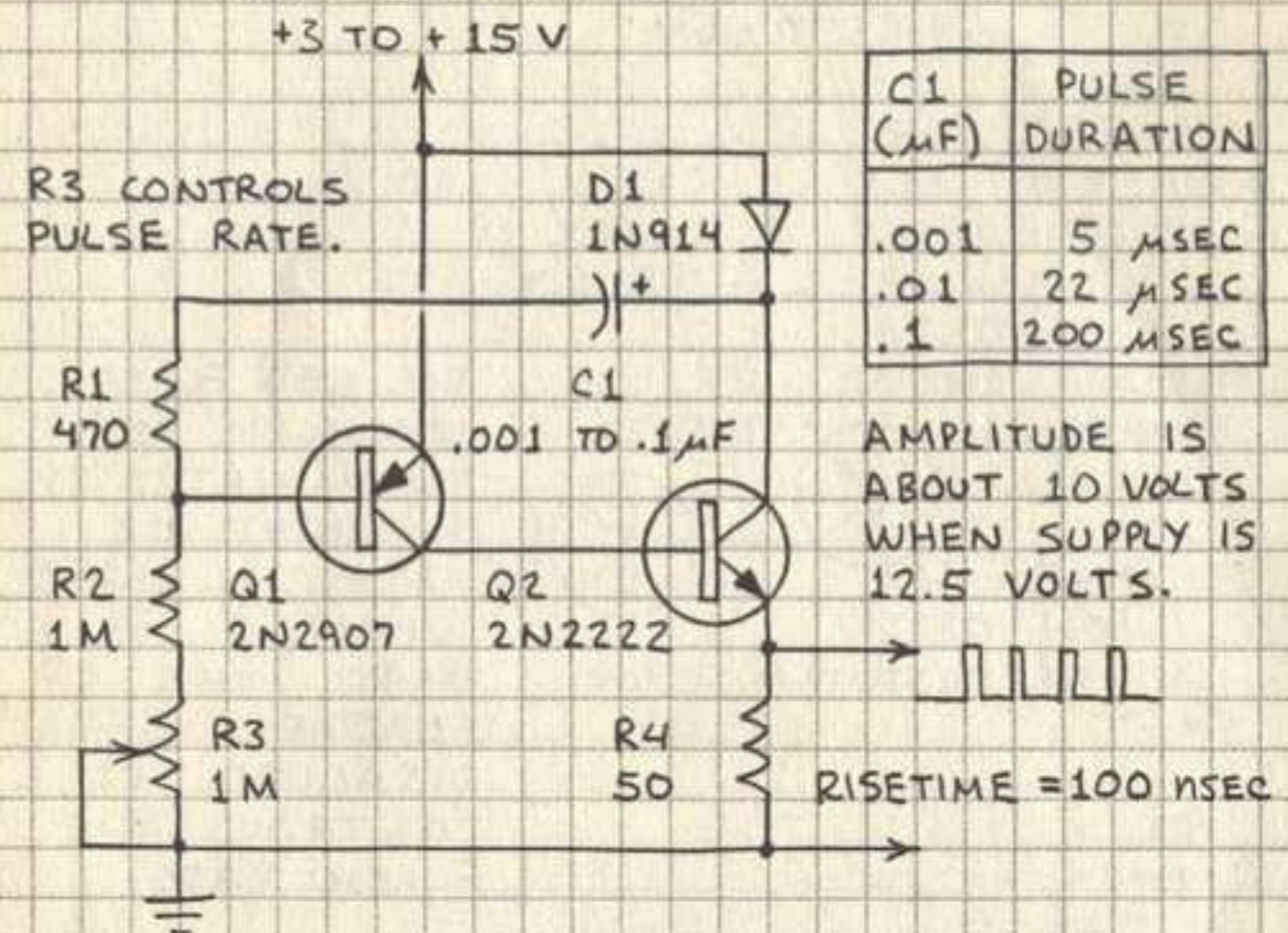
C1 (µF)	PULSE DURATION
.001	5 µSEC
.01	22 µSEC
.1	200 µSEC

AMPLITUDE IS
ABOUT 10 VOLTS
WHEN SUPPLY IS
12.5 VOLTS.

RISETIME = 100 nSEC

DC METER AMPLIFIER

+6V

Q1
2N3904

DC IN

UP TO 5
MICROAMPS
FULL SCALE.

D1
1N914

R2
1K

R1
10K

M1
0-1mA

R3
5K
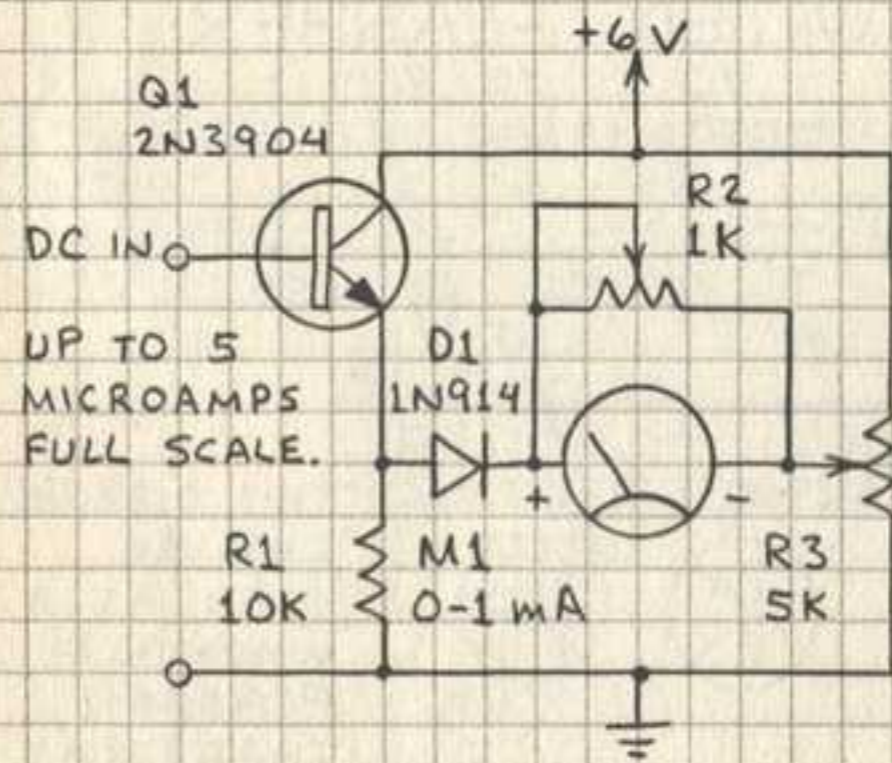
TO CALIBRATE,
FIRST CONNECT
INPUT TO +6V
THROUGH A
1M POT AND
A DIGITAL
MULTIMETER
SET TO READ
CURRENT IN
MILLIAMPERES.
THEN SET R2
AT ITS MID
POINT. NEXT:

1. SET 1M POT FOR DESIRED CURRENT.
2. ADJUST R3 UNTIL M1 INDICATES 1 mA.
3. REPEAT STEPS 1 AND 2.
4. ADJUST R2 UNTIL M1 INDICATES 1 mA.

LIGHT-ACTIVATED FLASHER

+4.5 TO +6V

C1
1 μF

LED

R1
1K

Q2
2N2907

Q3
2N2222

Q1
PHOTOTRANSISTOR

R2
2M
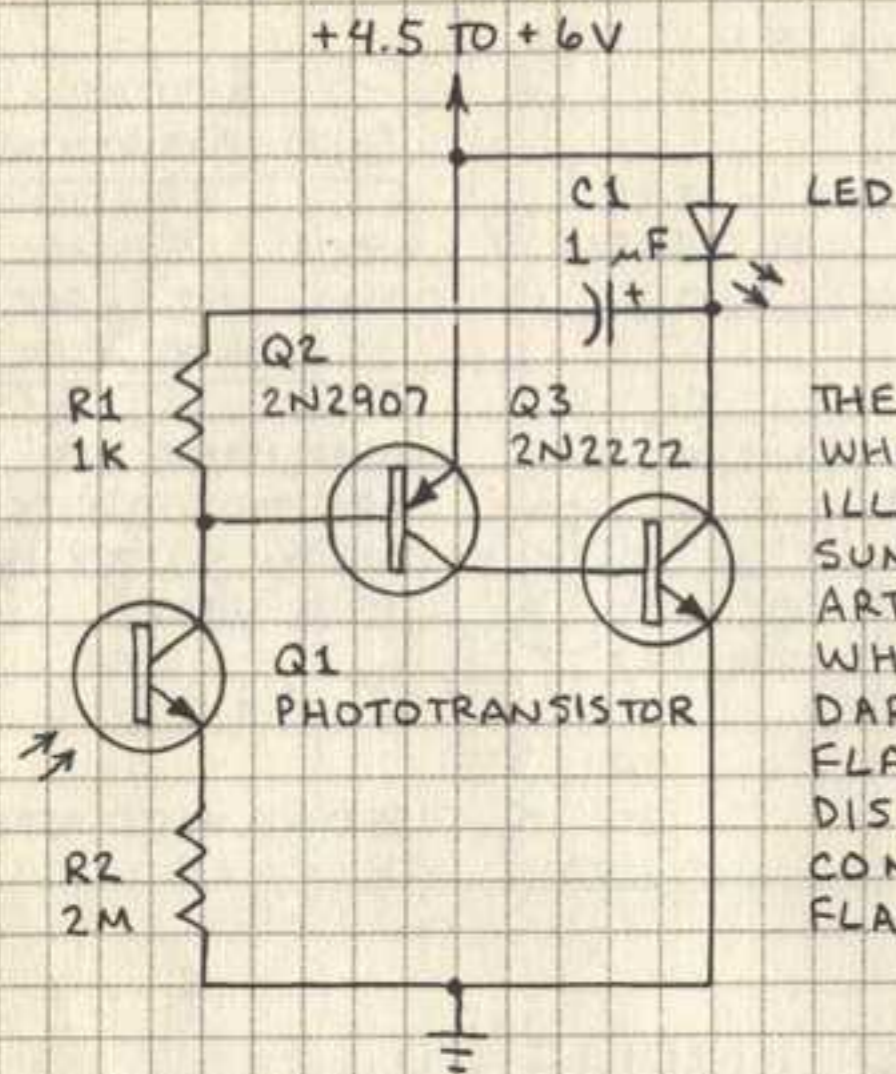
THE LED FLASHES
WHEN Q1 IS
ILLUMINATED BY
SUNLIGHT OR
ARTIFICIAL LIGHT.
WHEN Q1 IS
DARK, THE
FLASHER IS
DISABLED. C1
CONTROLS THE
FLASH RATE.

DARK-ACTIVATED FLASHER

+4.5 TO +6V

C1
1 μF

LED

R1
1K

Q2
2N2907

Q3
2N2222

R2
1M

Q1
PHOTO-
TRANSISTOR

THIS CIRCUIT
CAN BE
USED AS A
WARNING
FLASHER
THAT TURNS
ON AT
NIGHT. C1
CONTROLS
FLASH RATE.

HIGH-BRIGHTNESS FLASHER

+6V

R1
100K

R4
1K

Q2
2N2907

R2
1K

Q1
2N2222

R3
5.6K

C1
22 μF

R5
10

L1

THIS CIRCUIT
SENDS A HIGH-
CURRENT PULSE
TO LAMP L1
ABOUT ONCE
EACH SECOND.
R1 CONTROLS
FLASH RATE.
L1 IS A 14 OR
243 LAMP. DO
NOT ALLOW L1
TO STAY ON.

R1 - ADJUST WITH CARE.

LED TRANSMITTER/RECEIVER

+6V D1 Q1 R1 +9V
     1N914 PHOTOTRANSISTOR 47K

USE HIGH-
OUTPUT
INFRARED
LED.

C1
.02

R1
22K

Q2
2N2222

LED

R2
2.2M

Q1
2N2907

R2
4.7K

C1
.1 μF

Q2
2N2222

R3
4.7K

R4
4.7K

R5
22K

PIEZO
ALERTER ELEMENT

SENDS TONE OVER
LED BEAM. LENSES
WILL INCREASE RANGE.
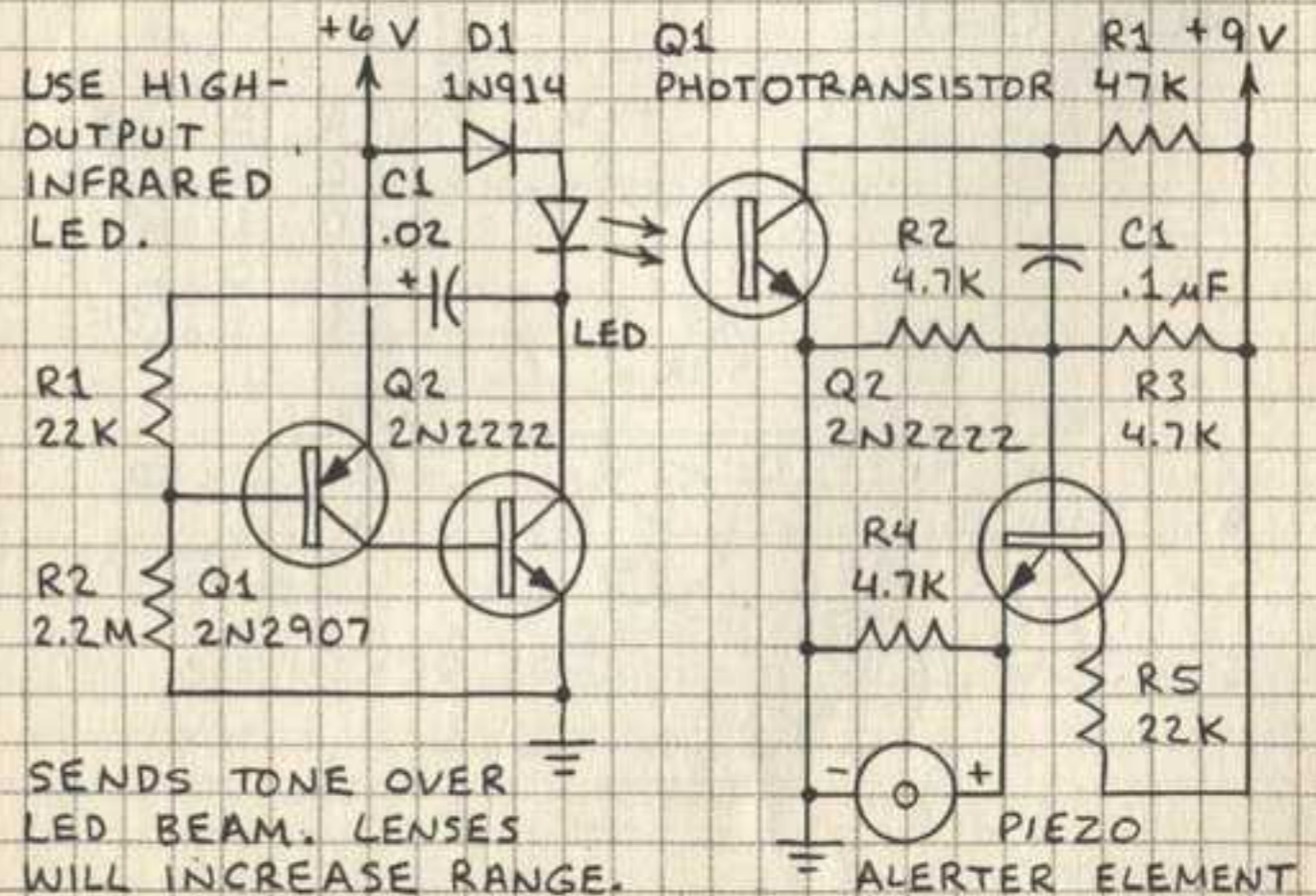
RESISTOR-TRANSISTOR LOGIC

THESE LOGIC CIRCUITS CAN BE USED TO
TEACH BASICS OF DIGITAL LOGIC AND IN
PRACTICAL APPLICATIONS.

OR GATE

O = GROUND
1 = +6 V

+6 V

R1 10K
R2 10K

Q1
Q2

R4 1K

R3 4.7K

Q1,Q2 = 2N2222

LED

A	B	LED
0	0	OFF
0	1	ON
1	0	ON
1	1	ON

NOR GATE

+6 V

R3 4.7K

R1 10K
R2 10K

Q1
Q2

R4 1K

LED

Q1,Q2 = 2N2222

A	B	LED
0	0	ON
0	1	OFF
1	0	OFF
1	1	OFF

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AND GATE

+6 V

R1 10K
A

R2 10K
B

Q1 2N2222

Q2 2N2222

R3 4.7K

R4 1K

LED

A	B	LED
0	0	OFF
0	1	OFF
1	0	OFF
1	1	ON

NAND GATE

+6V

R3 4.7K

R1 10K
A

R2 10K
B

Q1 2N2222

Q2 2N2222

R4 1K

LED

A	B	LED
0	0	ON
0	1	ON
1	0	ON
1	1	OFF

INVERTER

R1 10K
A

Q1 2N2222

R2 4.7K   +6 V

R3 1K   LED

A	LED
0	ON
1	OFF

37
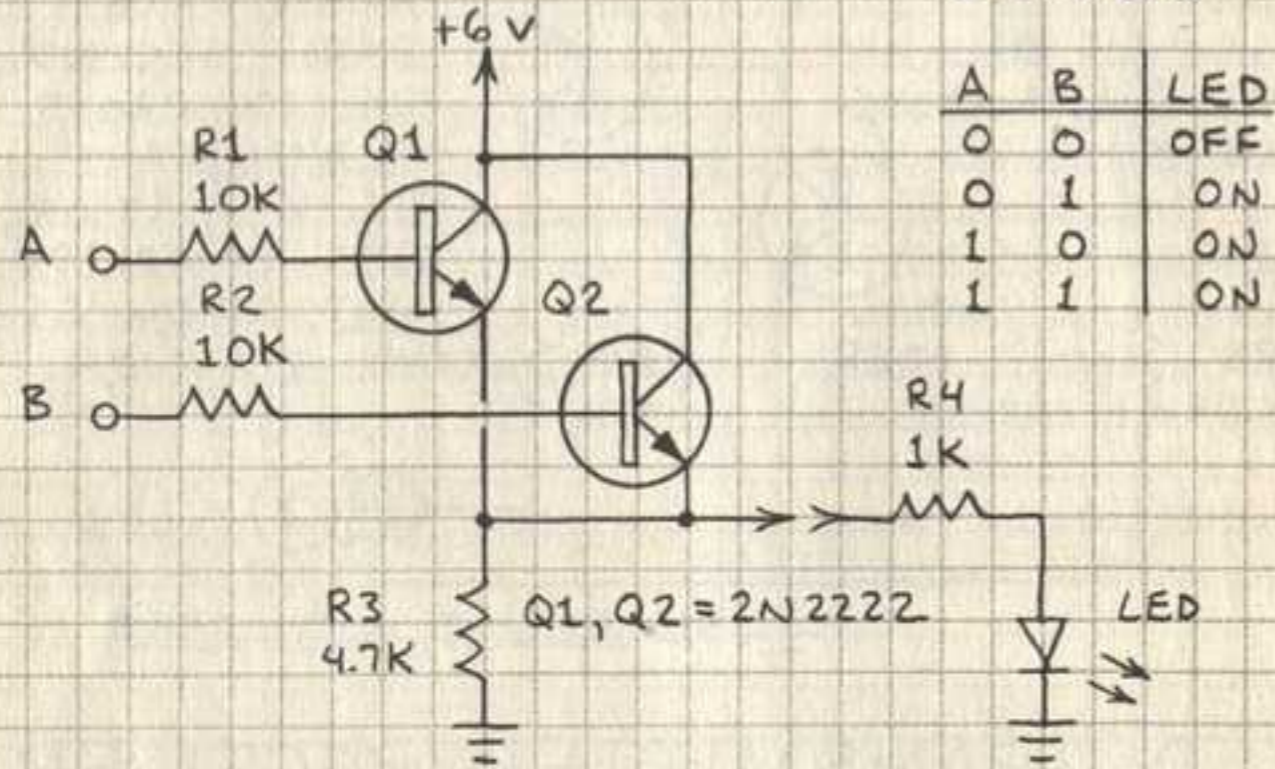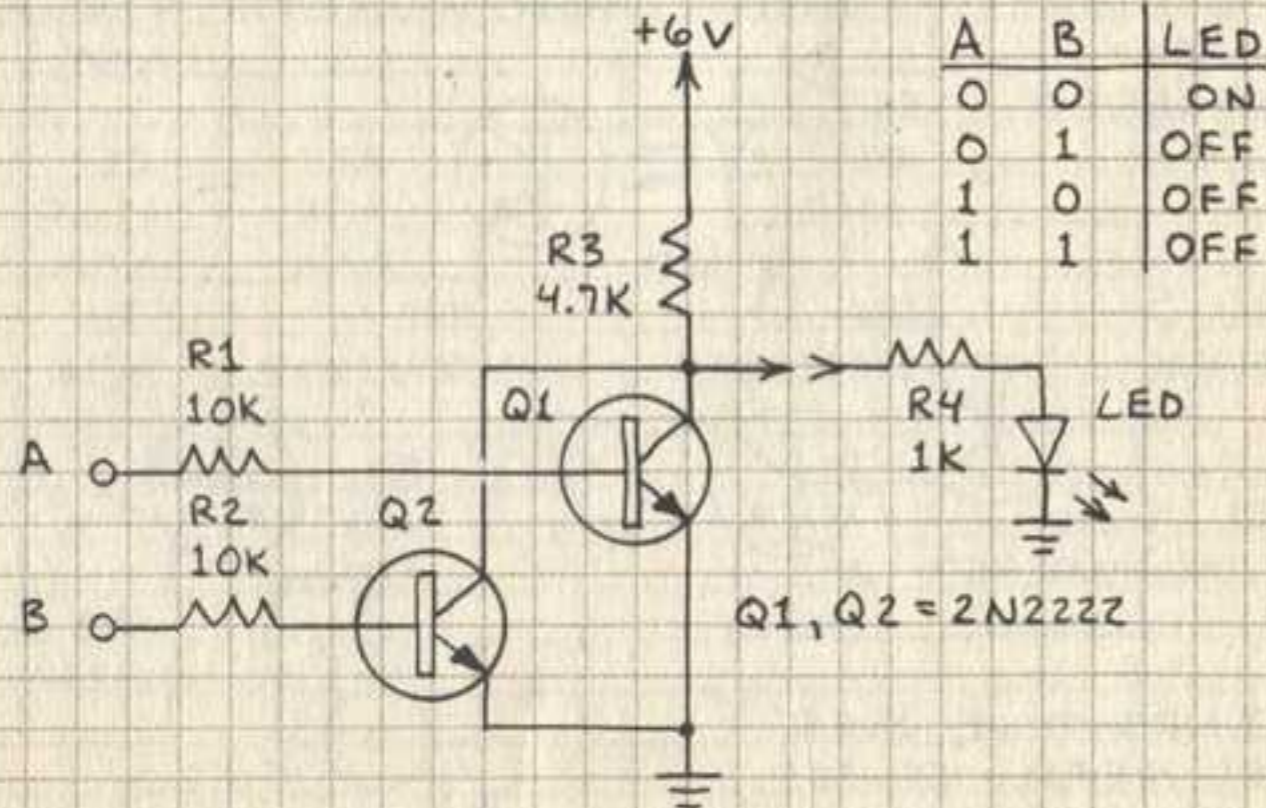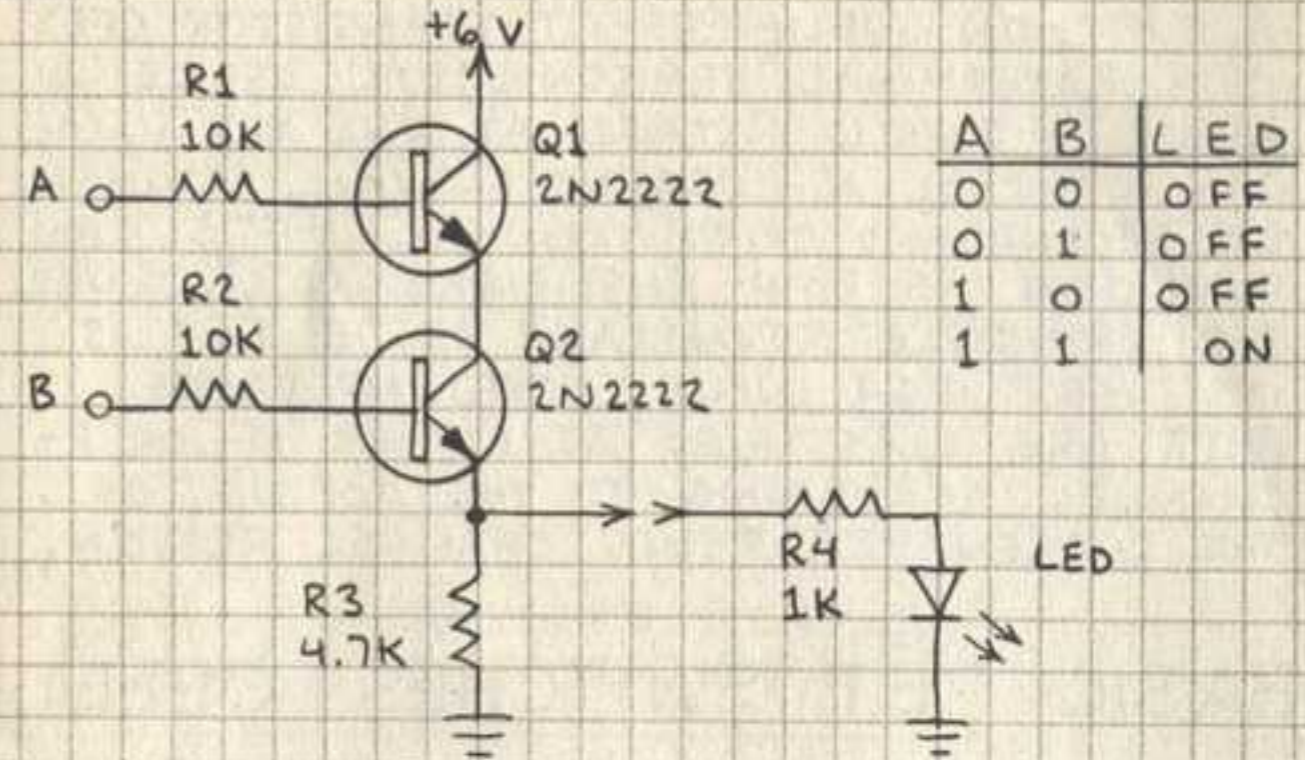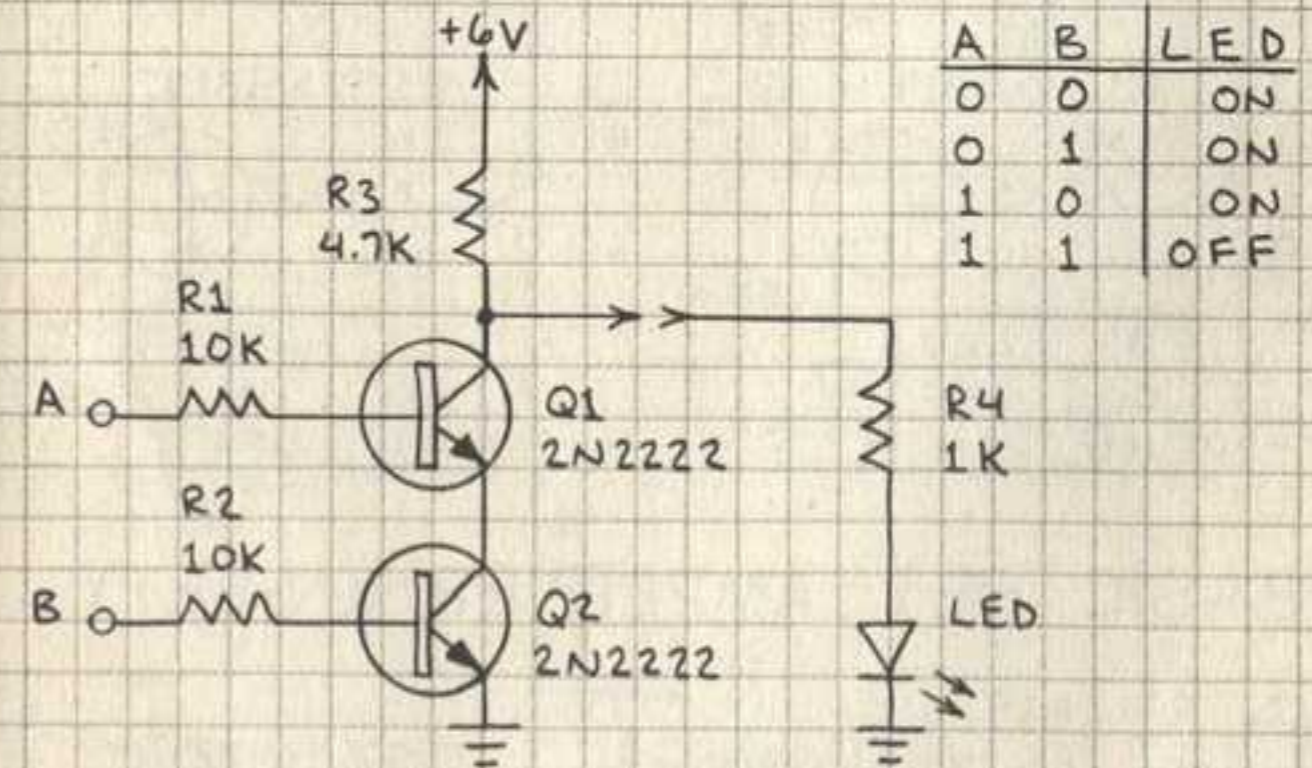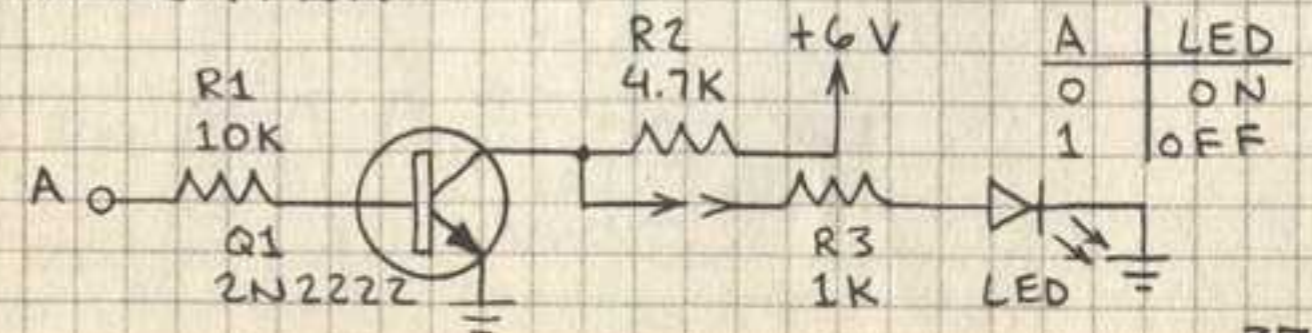
JUNCTION FETS

A JUNCTION FIELD-EFFECT TRANSISTOR (FET) IS A 3-TERMINAL SEMICONDUCTOR DEVICE IN WHICH A SMALL VOLTAGE AT ONE TERMINAL CAN CONTROL A CURRENT FLOWING BETWEEN THE SECOND AND THIRD TERMINAL. FETS CAN FUNCTION AS BOTH AMPLIFIERS AND SWITCHES. THE PRINCIPLE ADVANTAGE OF THE FET IS ITS VERY HIGH INPUT (GATE) IMPEDANCE. FETS ARE CLASSIFIED AS EITHER N- OR P-CHANNEL ACCORDING TO THE DOPING OF THE CURRENT-CARRYING CHANNEL REGION.

BASIC FET SWITCHES (N-FET)

NOTE: LO = -9V

S1	LED
LO	OFF
HI	ON

S1	LED
LO	ON
HI	OFF
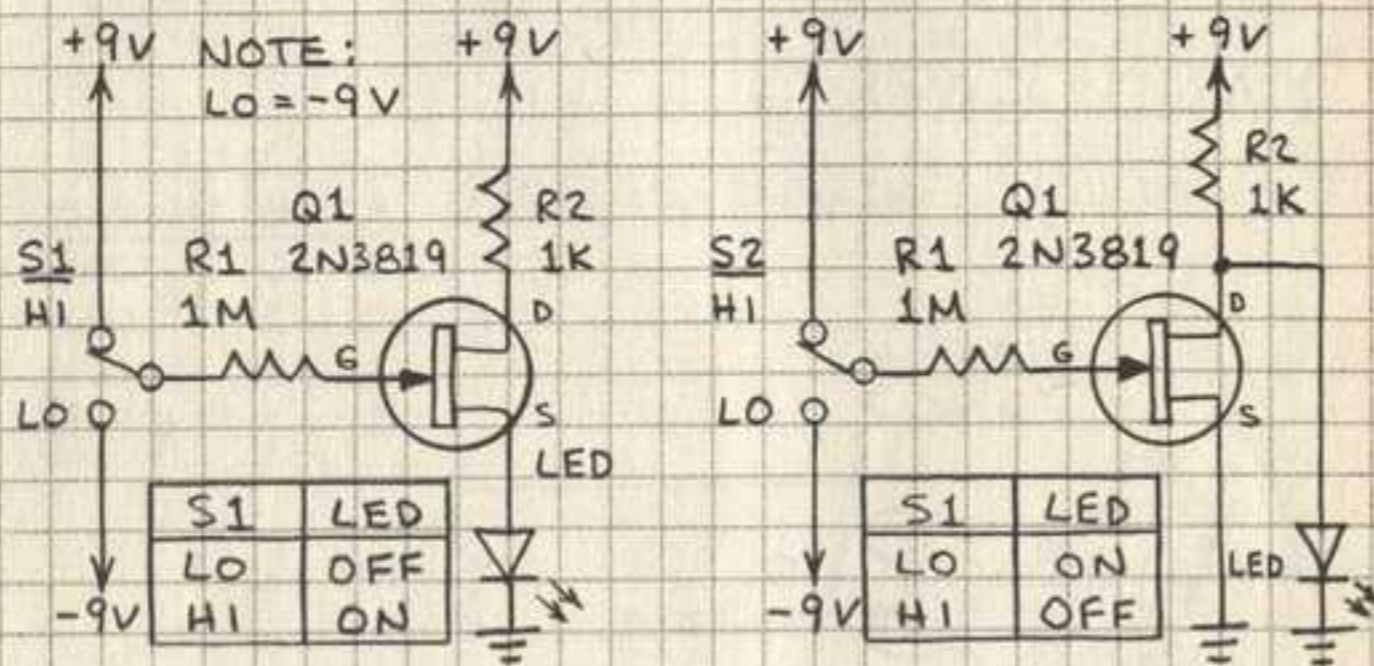
BASIC FET AMPLIFIER (N-FET)

2N3819
S G D

LOW GAIN; VERY HIGH INPUT IMPEDANCE.

TEST CIRCUIT GAVE GAIN $(V_{out}/V_{in}) = 2$.
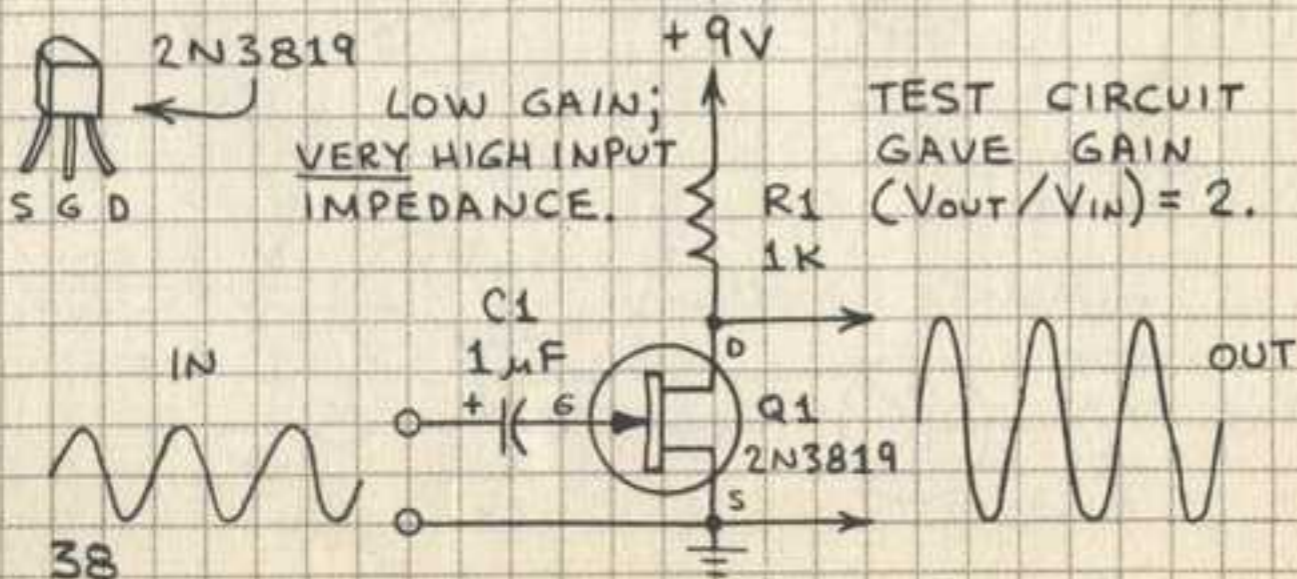
HI-Z MICROPHONE PREAMPLIFIER

USE TO COUPLE HIGH-IMPEDANCE CRYSTAL-TYPE MICROPHONES TO AMPLIFIER.

R2 IS GAIN CONTROL.
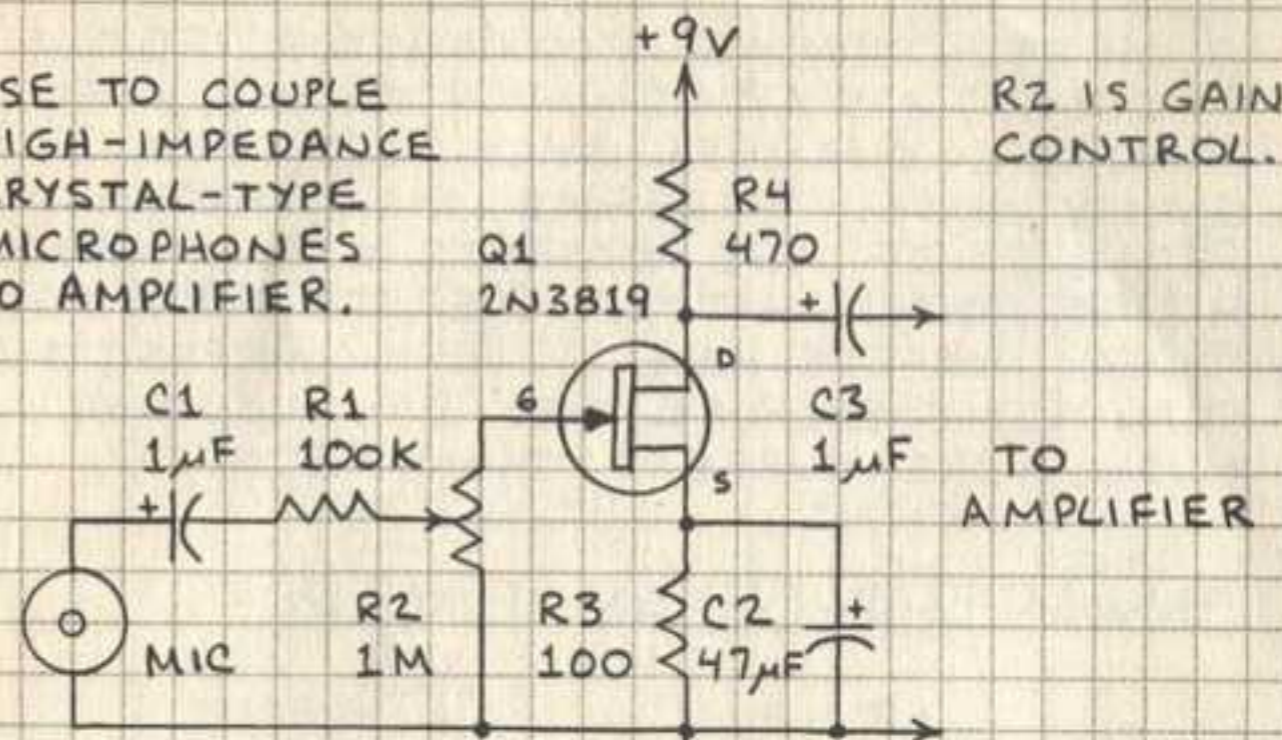
KEEP LEADS TO MICROPHONE SHORT OR USE SHIELDED CABLE.

HI-Z AUDIO MIXER

INPUTS: A, B

R1 AND R2 CONTROL GAIN FOR INPUTS A AND B.
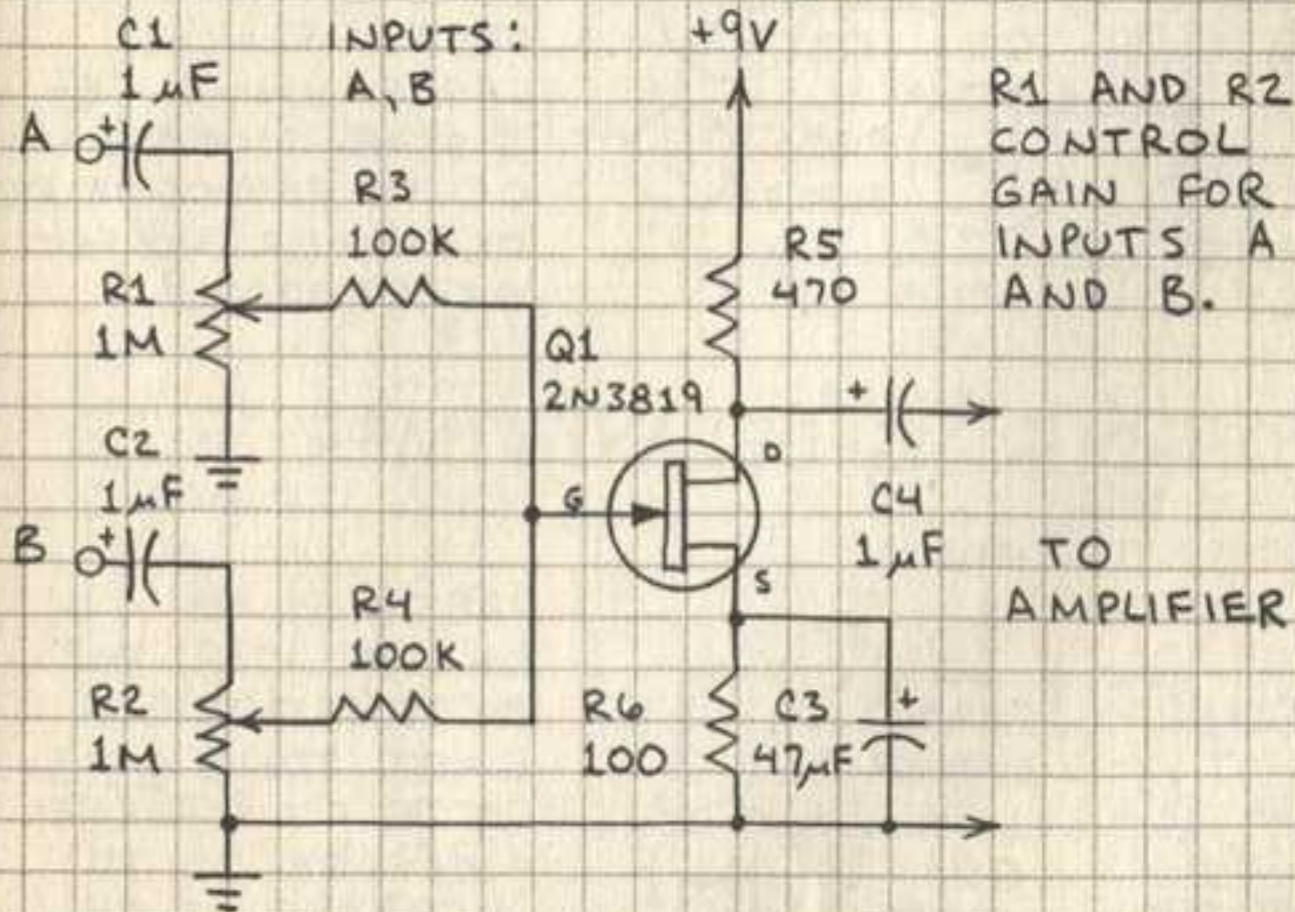
USE TO COMBINE SIGNALS FROM TWO OR MORE MICROPHONES, PREAMPLIFIERS, ETC.

POWER MOSFETS

A METAL-OXIDE-SEMICONDUCTOR FET (MOSFET) HAS A GATE WHICH IS INSULATED FROM THE CHANNEL BY A VERY THIN GLASSY OXIDE. THEREFORE THE INPUT IMPEDANCE OF THE MOSFET IS CONSIDERABLY HIGHER THAN THAT OF THE STANDARD FET. POWER MOSFETS HAVE A VERY LOW RESISTANCE CHANNEL. THEREFORE THEY CAN CONTROL MUCH MORE CURRENT THAN FETS.

ON-AFTER-DELAY TIMER
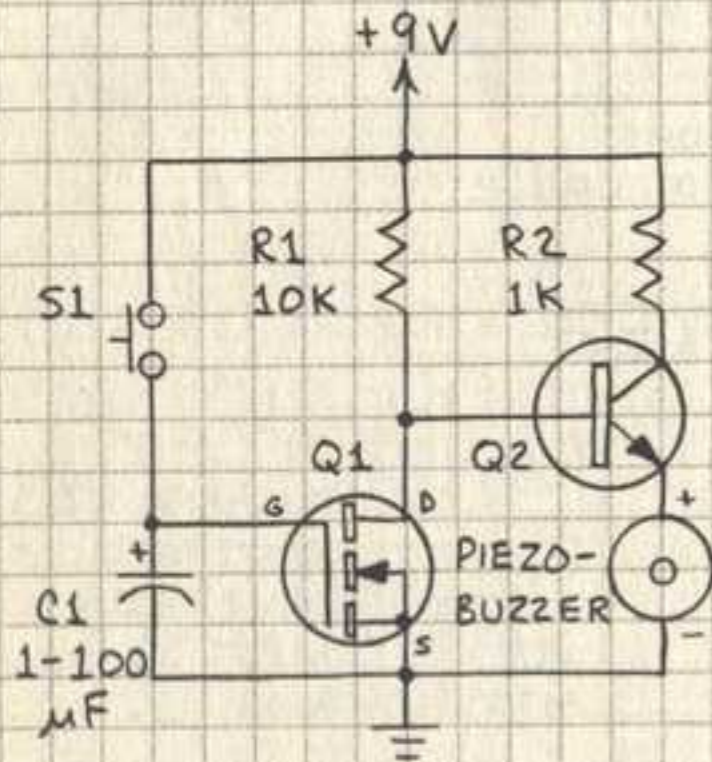
PRESS S1 TO CHARGE C1. THE PIEZO-BUZZER EMITS TONE AFTER C1 SELF DISCHARGES. LARGE VALUES FOR C1 INCREASE THE DELAY. PLACE LARGE VALUE RESISTOR ACROSS C1 TO REDUCE DELAY. Q1-POWER MOSFET. Q2-2N2222.

ON-DURING-DELAY TIMER
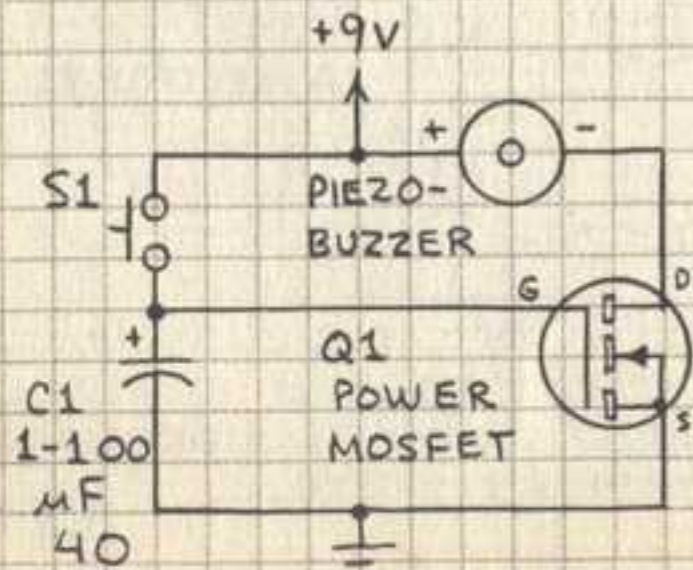
PRESS S1 TO CHARGE C1. THE PIEZO-BUZZER EMITS TONE UNTIL C1 SELF DISCHARGES. INCREASE C1 TO INCREASE DELAY. RESISTOR ACROSS C1 WILL REDUCE DELAY.

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HI-Z SPEAKER AMPLIFIER
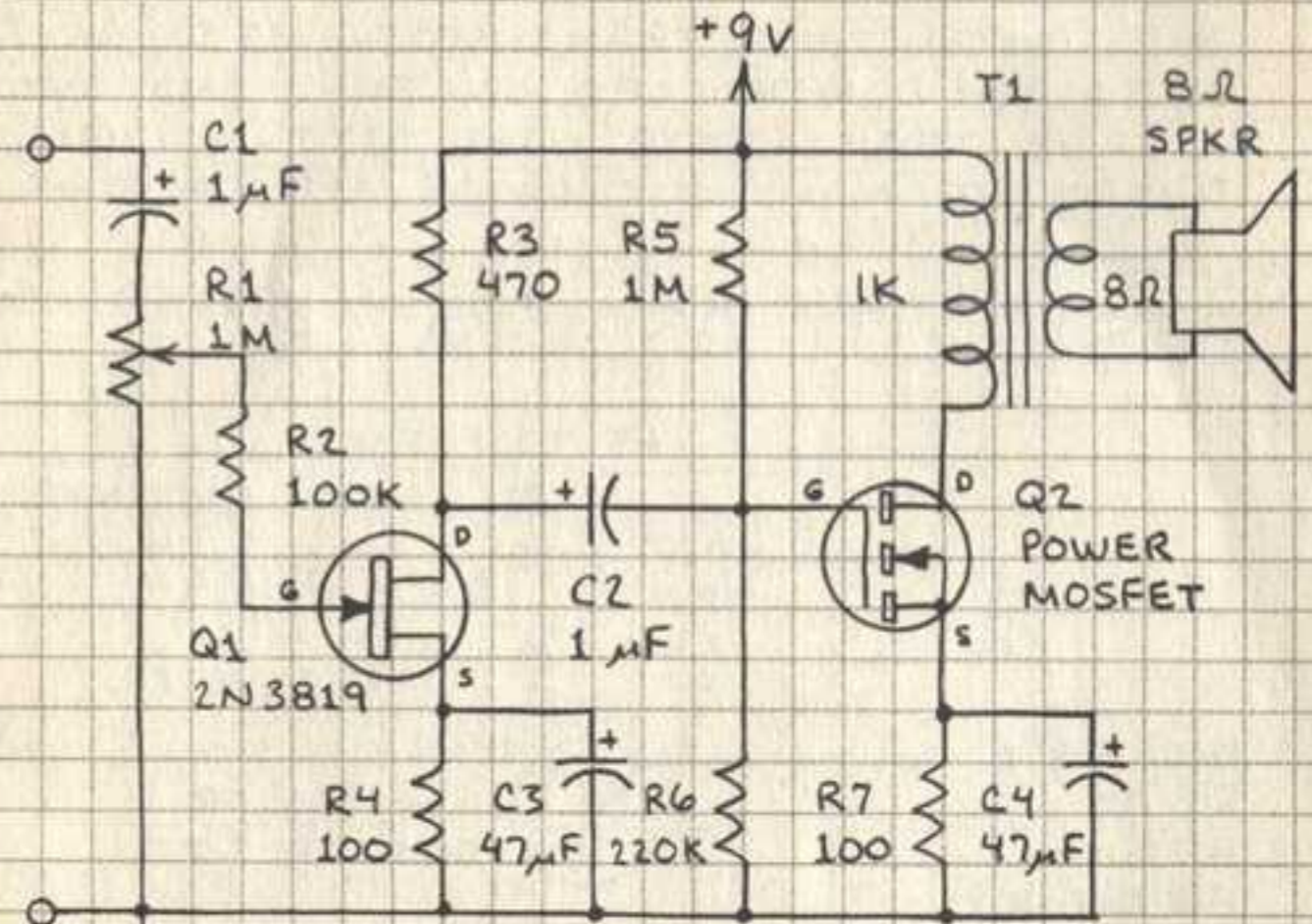
R1 CONTROLS GAIN. INPUT CAN BE HIGH-IMPEDANCE MICROPHONE, RADIO, ETC.

DUAL LED FLASHER
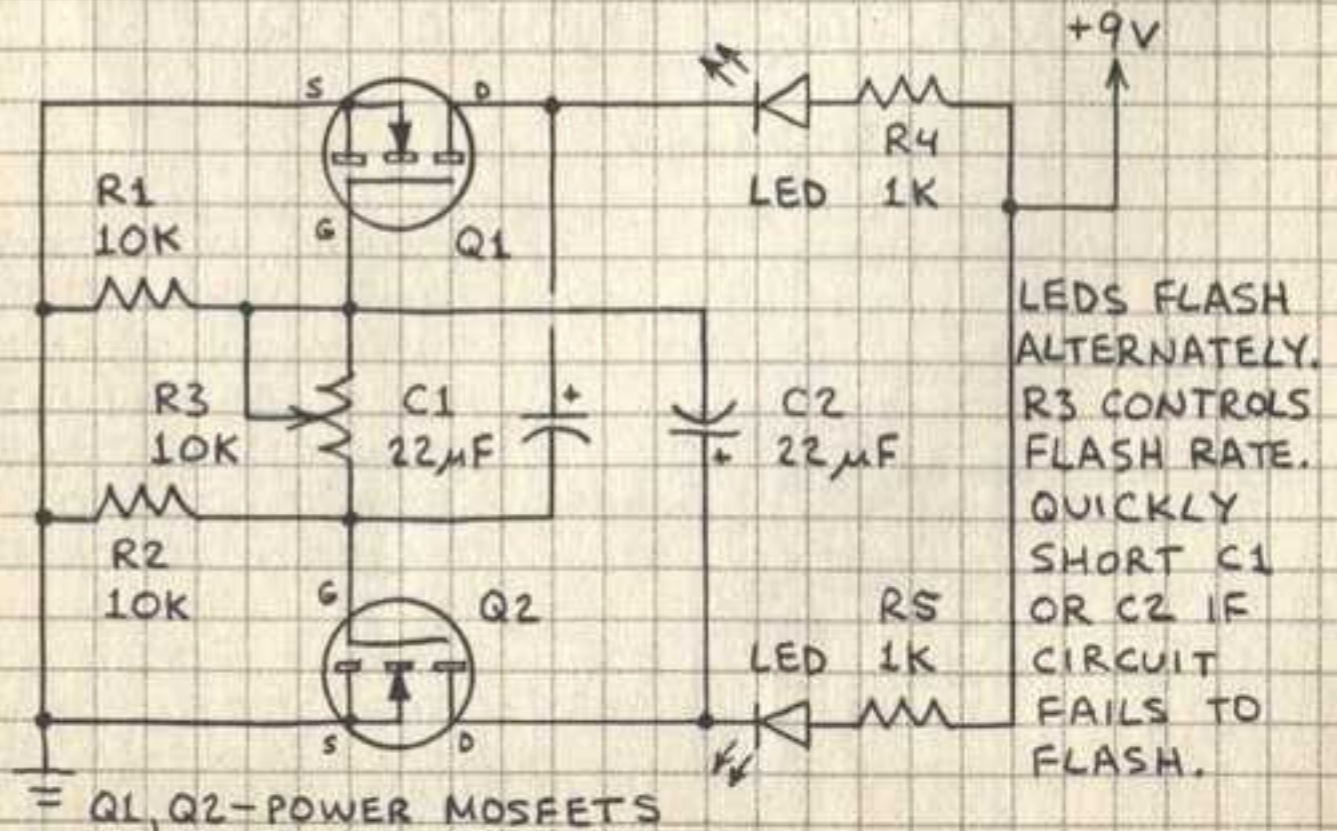
LEDS FLASH ALTERNATELY. R3 CONTROLS FLASH RATE. QUICKLY SHORT C1 OR C2 IF CIRCUIT FAILS TO FLASH.

Q1, Q2 - POWER MOSFETS

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UNIJUNCTION TRANSISTORS

THE UNIJUNCTION TRANSISTOR (UJT) IS A
VOLTAGE-CONTROLLED SWITCH AND NOT
A TRUE TRANSISTOR. THE UJT IS WELL
SUITED FOR MANY OSCILLATOR APPLICATIONS.

BASIC UJT OSCILLATOR

+5 TO +18V

2N4891

B1 E B2

R1 1M
R2 2.2K
R3 100

INCREASE R1 TO REDUCE FREQUENCY.

E   B2 Q1
2N4891 OR
SIMILAR UJT

B1

C1 .001 TO 1 µF

R4 100

OUT   OUT

LOW-VOLTAGE INDICATOR

+3 TO +18V

R2 4.7K
R3 100
R1 50K

E   B2 Q1
2N4891, ETC.
B1

C1 .047
D1 ZENER
8Ω SPKR

SOUNDS WARNING
TONE WHEN THE
SUPPLY VOLTAGE
FALLS BELOW D1's
TURN-ON VOLTAGE.
SELECT D1 FOR
DESIRED VOLTAGE.
OK TO USE A
SINGLE FIXED
CAPACITOR FOR
R1 AND R2 (4.7K
GIVES 2.8 KHz).
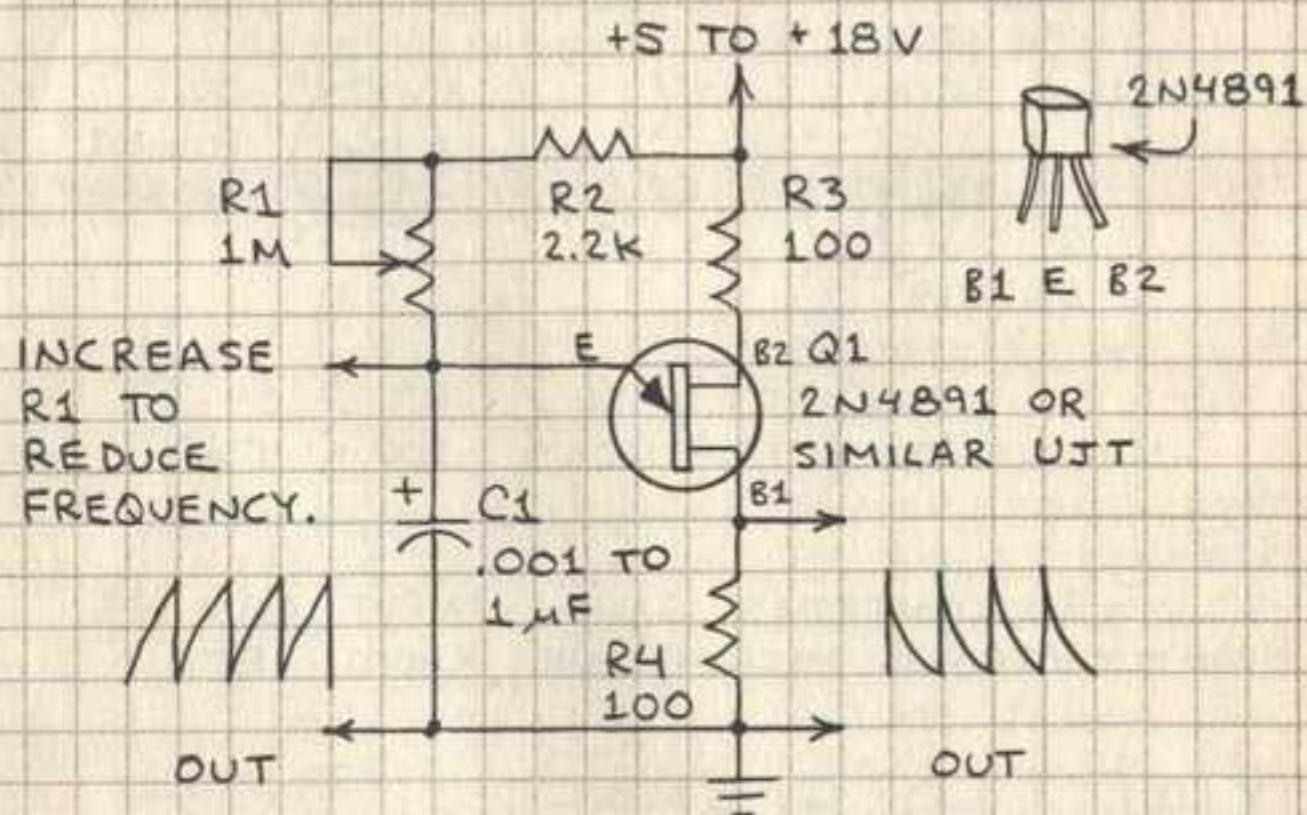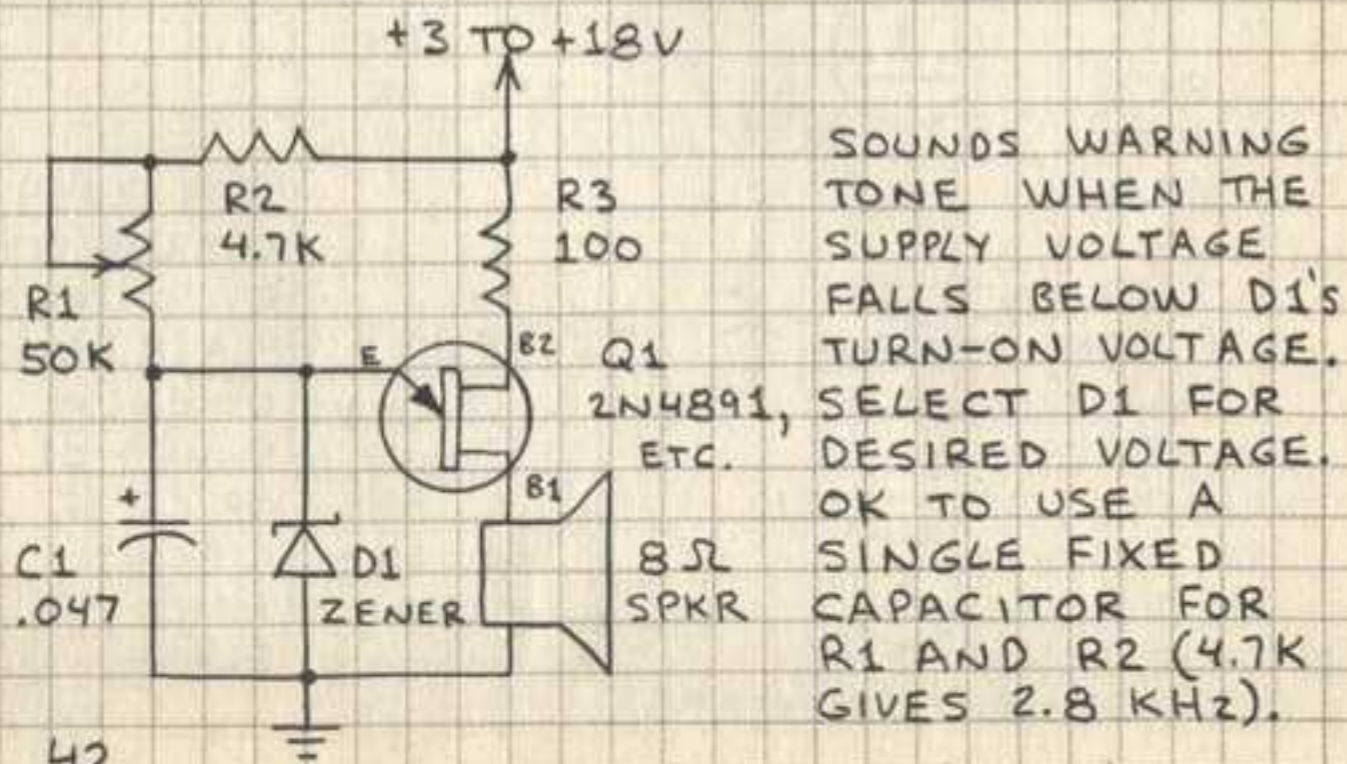
SOUND-EFFECTS GENERATOR

+6 TO +12 V

R1 100
R3 100K
R4 1M
R5 100

Q1, Q2
2N4891,
ETC.

B2   E   Q1
B1

R6 100K

E   B2   Q2
B1

R2 47
C1 4.7µF
C2 .001µF
R7 47
TO AMPLIFIER

THIS CIRCUIT GENERATES CHIRPS HAVING A FRE-
QUENCY CONTROLLED BY R4. R3 CONTROLS RATE.

1-MINUTE TIMER

+9V

R1 100K
R3 100

R2 4.7K
Q1 2N4891, ETC.

E   B2

B1

C1 470µF
D1 1N914
RELAY 275-004

THIS CIRCUIT PULLS
IN THE RELAY AT
A REPETITIVE CYCLE
CONTROLLED BY R1.
RELAY MUST BE LOW-
VOLTAGE TYPE.

R1 + R2 (OHMS)	DELAY (SEC.)
10 K	7
15 K	10
22 K	12
47 K	27
100 K	68

PIEZOELECTRIC BUZZERS

PIEZO BUZZERS DELIVER EAR-PIERCING TONE AT LOW DRIVE CURRENT AND VOLTAGE.

<u>CAUTION</u>: USE EAR PROTECTORS WHEN EXPERIMENTING WITH PIEZO BUZZERS AT CLOSE RANGE FOR MORE THAN BRIEF INTERVALS.

BELL   VOLUME CONTROL

+3 TO +12V

S1   OK TO ALTER C1'S VALUE.

C1 47µF

← PIEZO BUZZER →

+3 TO +12V

R1 — 10K TO 50K POTENTIOMETER

R1

PRESS AND RELEASE S1 TO SIMULATE BELL.   R1 CONTROLS VOLUME.

LOGIC INTERFACES

+5 TO +12V

R1 1K   Q1 2N2222

IN

IN	TONE
LO	OFF
HI	ON

+5 TO +12V

R2 1K

R1 1K   Q1 2N2222

IN

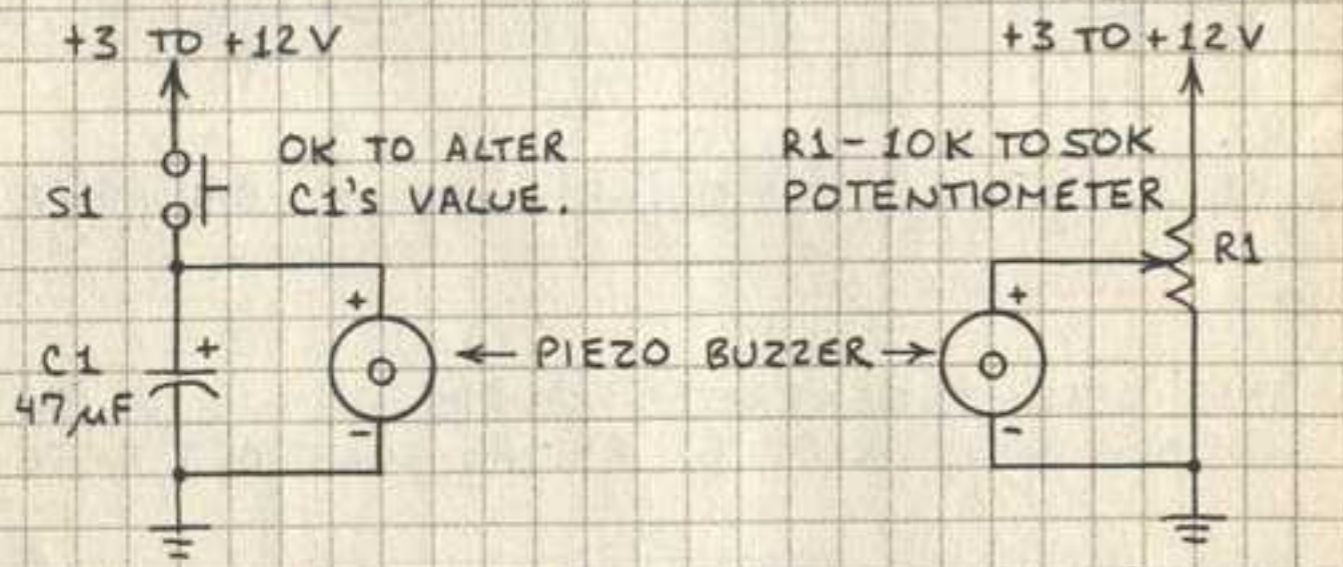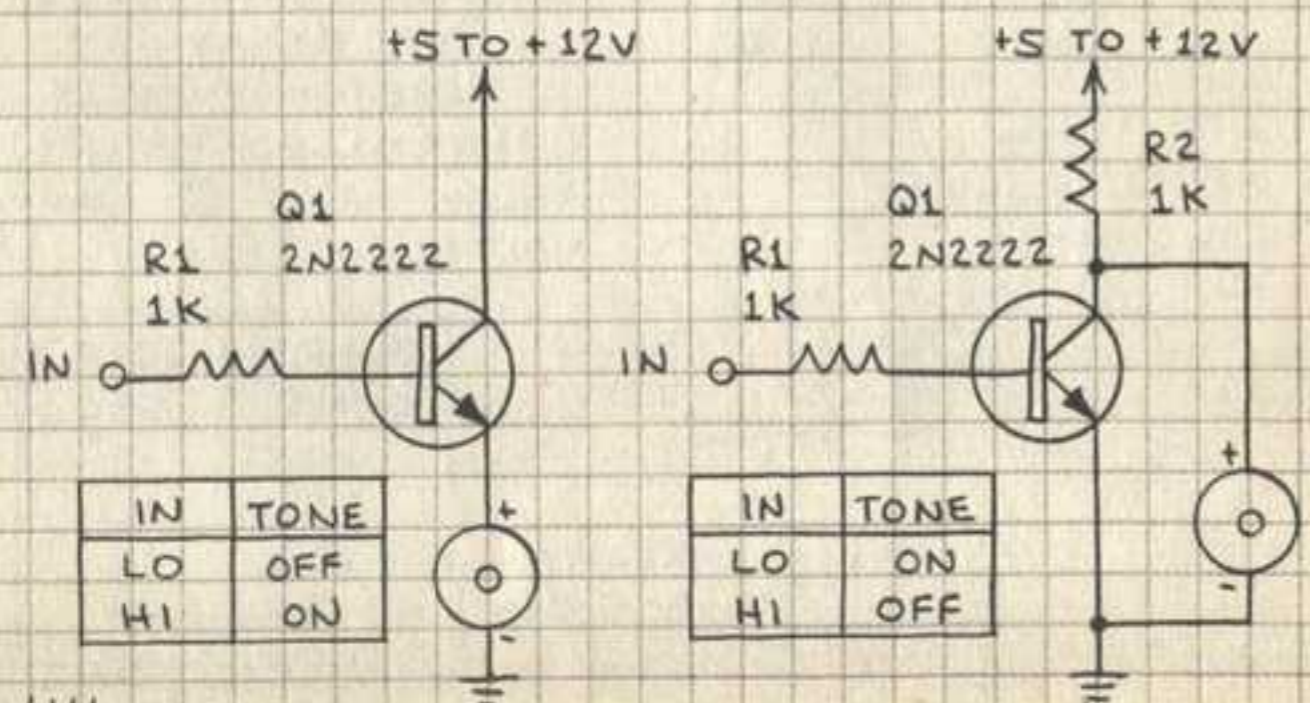| IN	TONE
LO	ON
HI	OFF

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PIEZO-ELEMENT DRIVERS

FIXED TONE

+3 TO +15V

R1 220K

R2 10K

BLUE   RED

BLACK

R3 470

Q1 2N2222
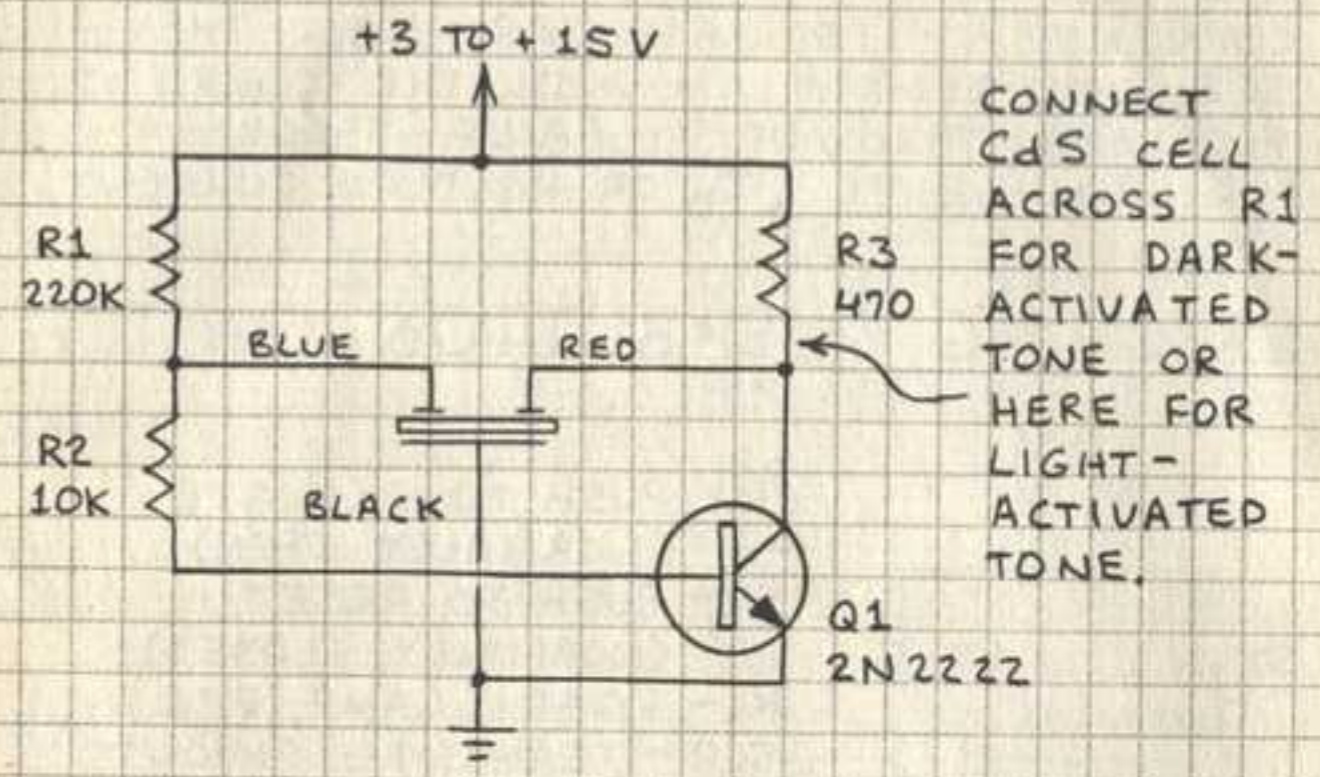
CONNECT CdS CELL ACROSS R1 FOR DARK-ACTIVATED TONE OR HERE FOR LIGHT-ACTIVATED TONE.

ADJUSTABLE FREQUENCY

+1 TO +15V

R4
BLUE 1K RED

BLACK

Q1 2N2907

R1 1K

R2 1M

Q2 2N2222

R3 220K
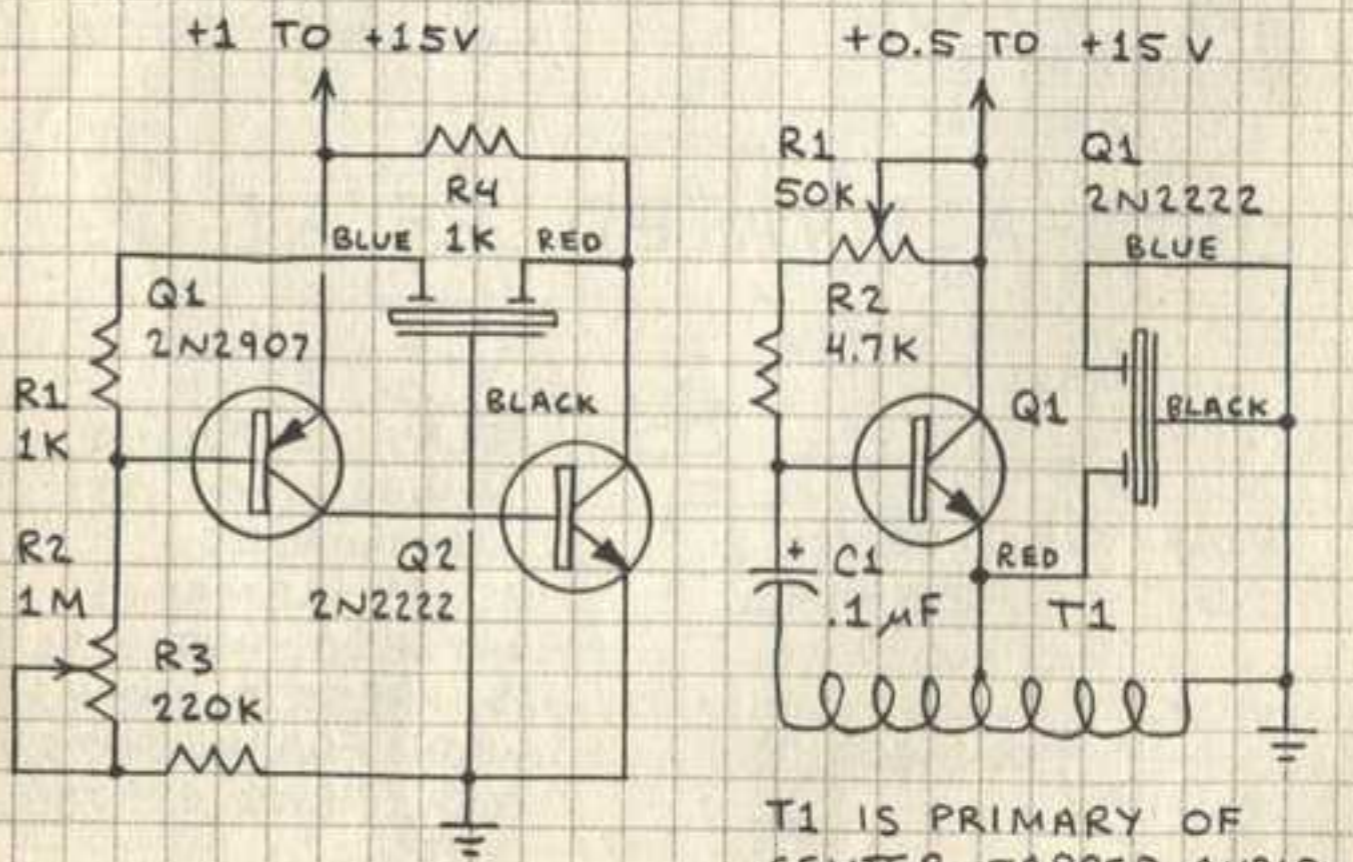
THIS CIRCUIT CAN BE EASILY MINIATURIZED. R2 CONTROLS FREQUENCY.

+0.5 TO +15V

R1 50K   Q1 2N2222

BLUE

R2 4.7K

Q1

BLACK

+ C1 .1µF   RED

T1

T1 IS PRIMARY OF CENTER-TAPPED AUDIO TRANSFORMER (RADIO SHACK 273-1380). R1 CONTROLS FREQUENCY.

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SILICON-CONTROLLED RECTIFIERS

THE SILICON-CONTROLLED RECTIFIER (SCR) IS A TRUE SOLID-STATE ON-OFF SWITCH. THE SCR IS SWITCHED ON BY A SMALL CURRENT AT ITS GATE TERMINAL. THE SCR WILL REMAIN ON UNTIL THE CURRENT FLOWING THROUGH IT FALLS BELOW A MINIMUM LEVEL (I_H OR HOLDING CURRENT).

LATCHING PUSHBUTTON SWITCH

S1 - PUSH TO ACTUATE
(NORMALLY OPEN)
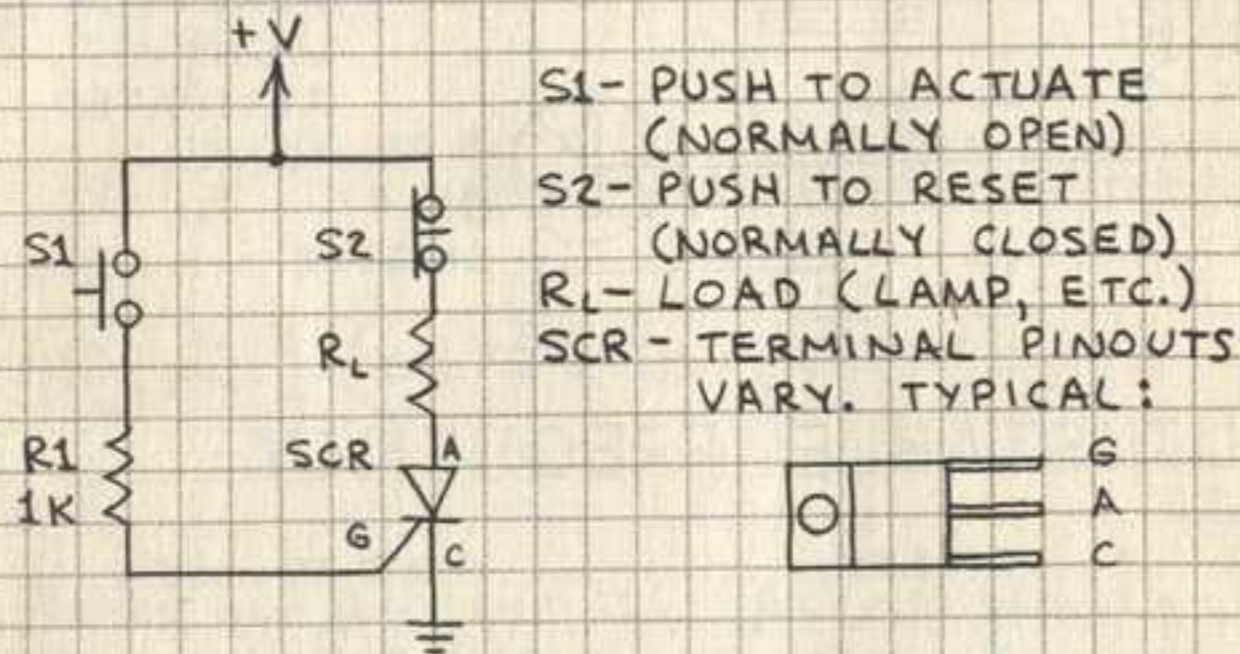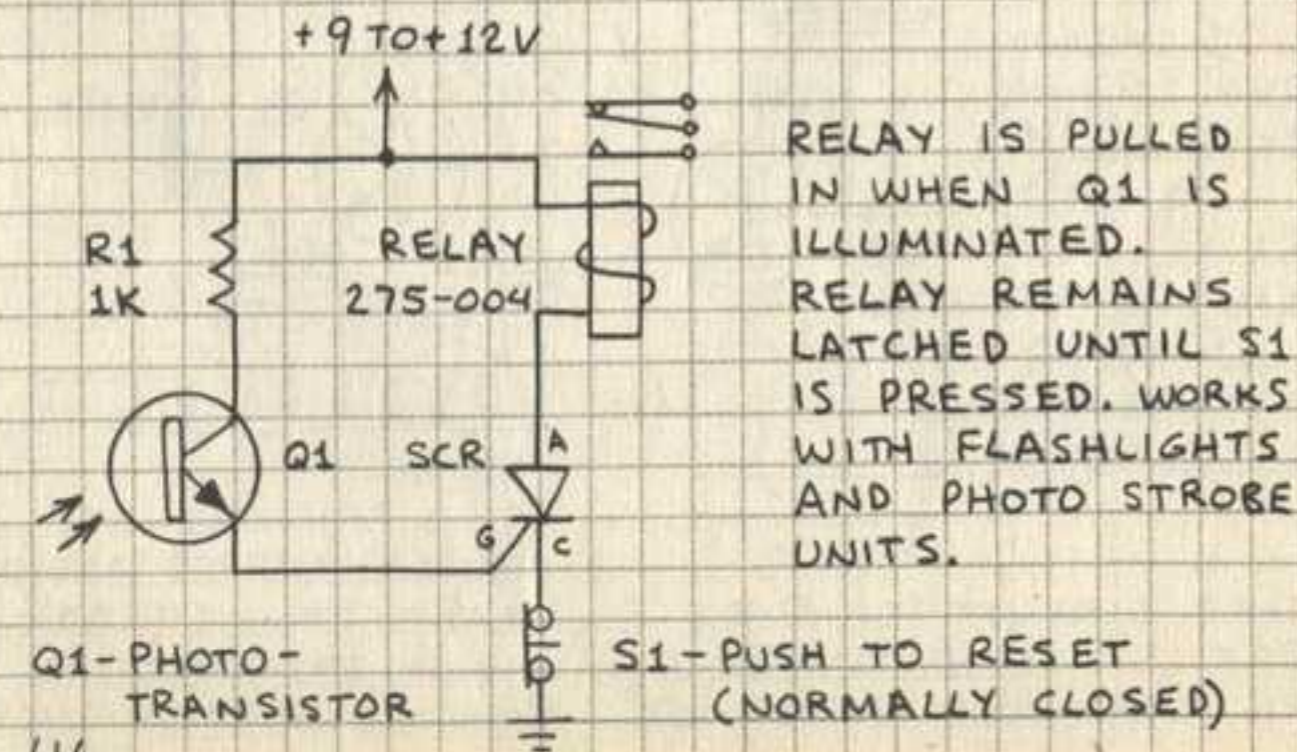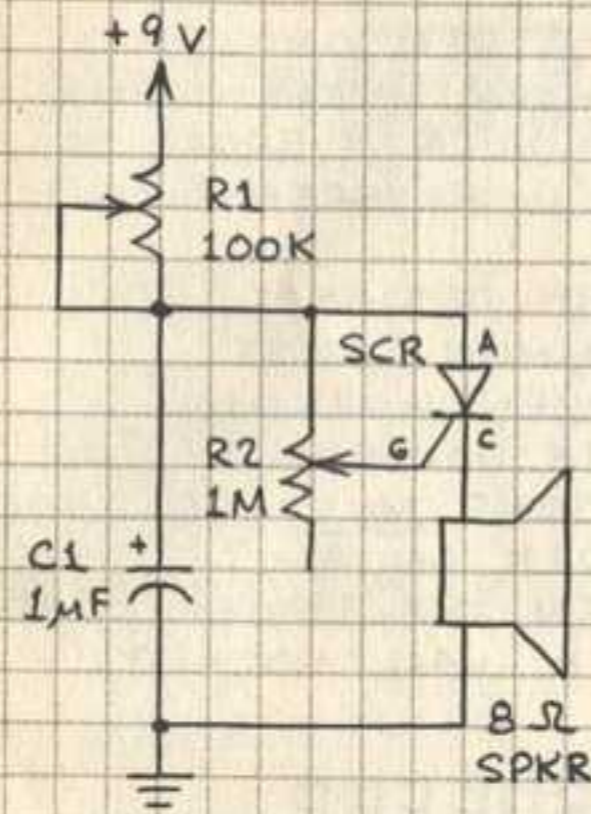S2 - PUSH TO RESET
(NORMALLY CLOSED)
R_L - LOAD (LAMP, ETC.)
SCR - TERMINAL PINOUTS
VARY. TYPICAL:

LIGHT-ACTIVATED RELAY

RELAY IS PULLED IN WHEN Q1 IS ILLUMINATED. RELAY REMAINS LATCHED UNTIL S1 IS PRESSED. WORKS WITH FLASHLIGHTS AND PHOTO STROBE UNITS.

Q1 - PHOTO-
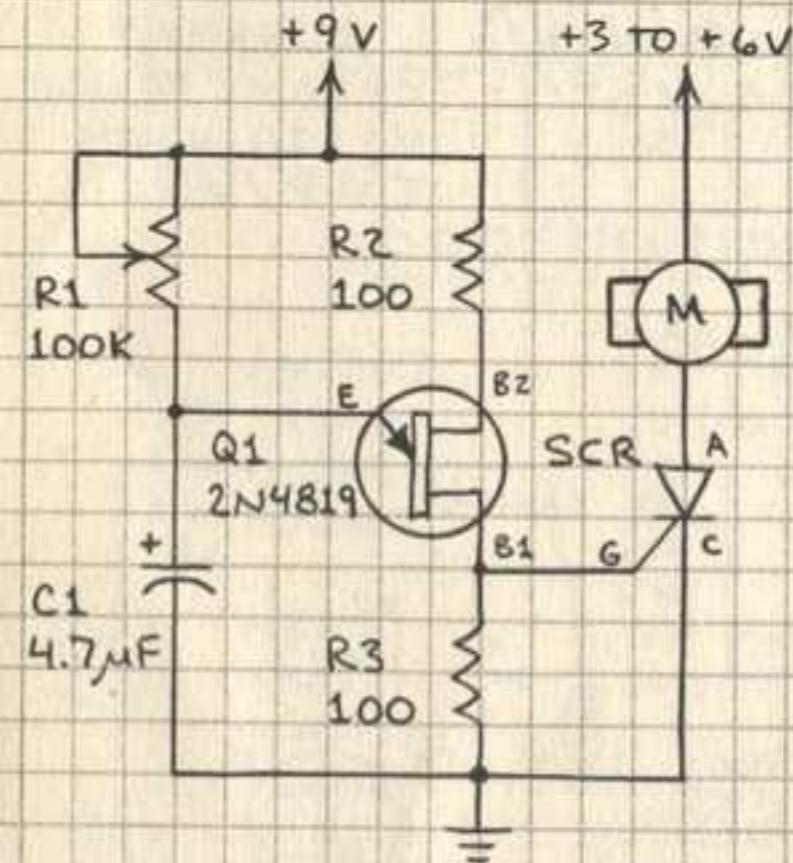TRANSISTOR

S1 - PUSH TO RESET
(NORMALLY CLOSED)

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RELAXATION OSCILLATOR

C1 IS CHARGED THROUGH R1 UNTIL ITS CHARGE IS HIGH ENOUGH TO SWITCH ON THE SCR THROUGH R2. C1 THEN DISCHARGES THROUGH THE SCR AND THE SPEAKER. R1 CONTROLS THE REPETION RATE.

NOTE: SOME SCRs REQUIRE CAREFUL ADJUSTMENT OF R2.

DC MOTOR SPEED CONTROLLER

THIS CIRCUIT WILL VARY THE SPEED OF SELECTED* DC MOTORS. R4 CONTROLS THE SPEED. AT SLOW PULSE RATES FROM THE UJT OSCILLATOR, THE MOTOR WILL ROTATE IN BURSTS. FOR BEST RESULTS, USE A SEPARATE POWER SUPPLY FOR THE MOTOR.

*CHECK MOTOR WITH THIS CIRCUIT. IF LED FLASHES ON AND OFF WHEN SHAFT OF MOTOR IS ROTATED, IT WILL PROBABLY WORK.
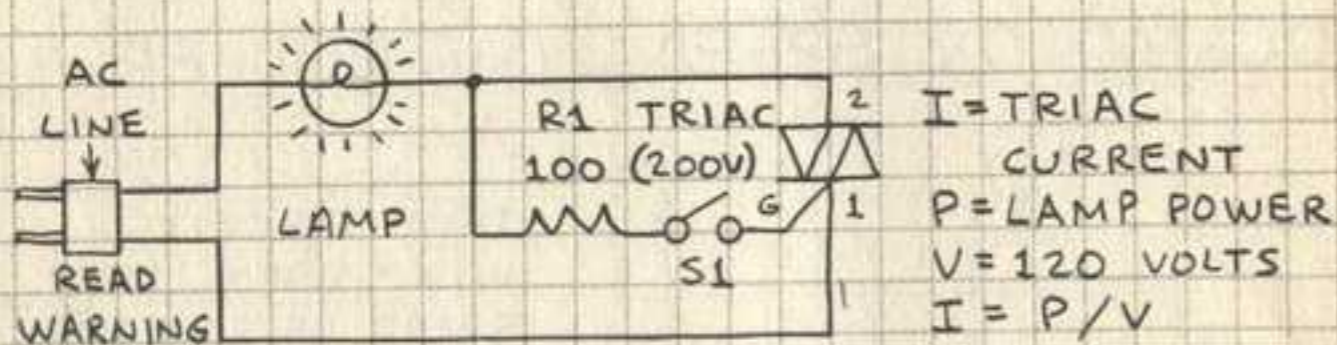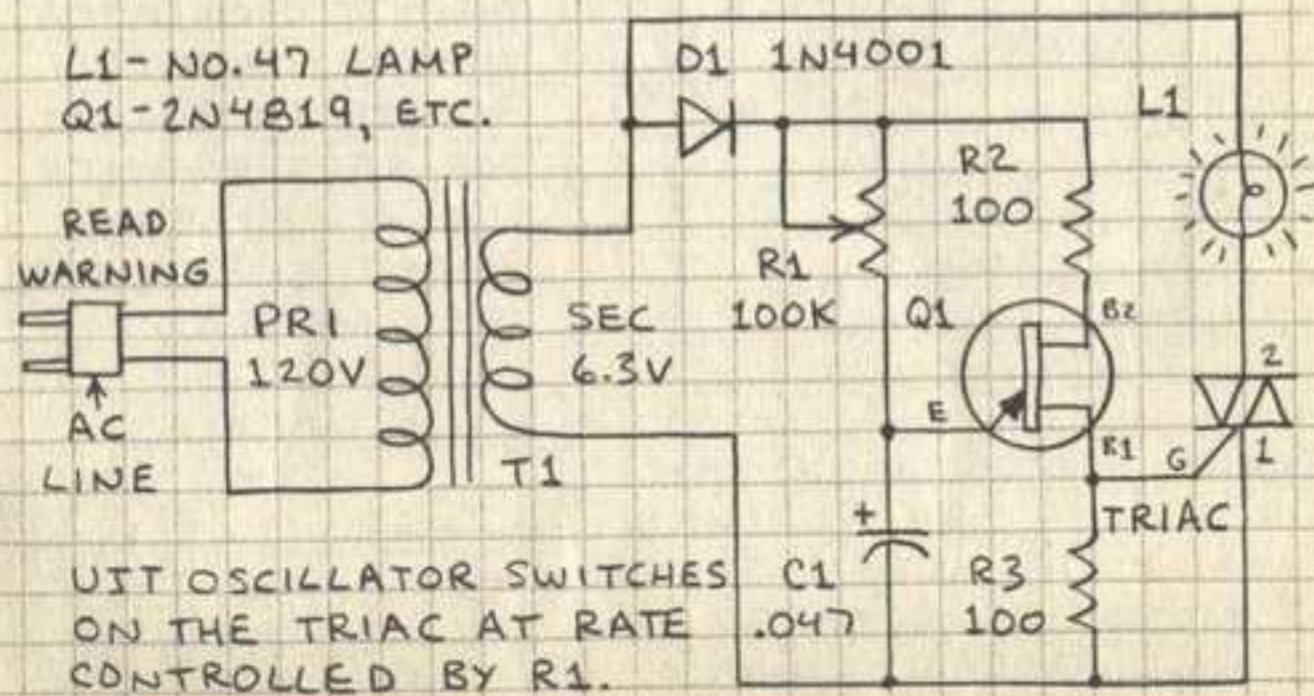
47
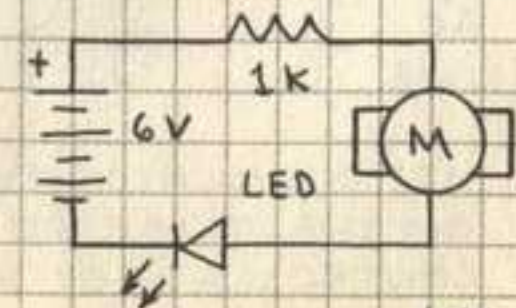
TRIACS

THE TRIAC IS A SOLID-STATE ON-OFF
SWITCH THAT CAN CONTROL ALTERNATING
CURRENT. IT IS ELECTRONICALLY EQUAL TO
TWO SCRs CONNECTED IN REVERSE-PARALLEL.

<u>WARNING</u>: TRIACS ARE DESIGNED FOR
AC OPERATION. USE COMMON SENSE
SAFETY PRECAUTIONS WHEN WORKING
WITH CIRCUITS THAT USE HOUSEHOLD LINE
CURRENT. <u>ALL</u> CONNECTIONS <u>MUST</u> BE WELL
INSULATED. <u>NEVER</u> WORK ON AN AC LINE
POWERED CIRCUIT WHEN THE POWER CORD
PLUG IS INSERTED IN A WALL SOCKET.

TRIAC SWITCH BUFFER

AC
LINE

LAMP

READ
WARNING

R1 TRIAC
100 (200V)
S1

I = TRIAC
CURRENT
P = LAMP POWER
V = 120 VOLTS
$I = P/V$

LAMP DIMMER

L1 - NO. 47 LAMP
Q1 - 2N4819, ETC.

READ
WARNING

PRI
120V

SEC
6.3V

AC
LINE

T1

D1 1N4001

R2
100

R1
100K Q1

C1
.047

R3
100

L1

TRIAC

UJT OSCILLATOR SWITCHES
ON THE TRIAC AT RATE
CONTROLLED BY R1.

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RESISTOR COLOR CODE

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

FOURTH BAND INDICATES TOLERANCE (ACCURACY):
GOLD = ±5%   SILVER = ±10%   NONE = ±20%

OHM'S LAW:

$V = IR$ $R = V/I$
$I = V/R$ $P = VI = I^2R$

ABBREVIATIONS

A = AMPERE	R = RESISTANCE
F = FARAD	V (OR E) = VOLT
I = CURRENT	W = WATT
P = POWER	Ω = OHM

M (MEG-) = × 1,000,000
K (KILO-) = × 1,000
m (MILLI-) = .001
μ (MICRO-) = .000 001
n (NANO-) = .000 000 001
p (PICO-) = .000 000 000 001