DATA

Book 1

Compiled from many sources, including the web, books from other authors and articles produced by Colin Mitchell

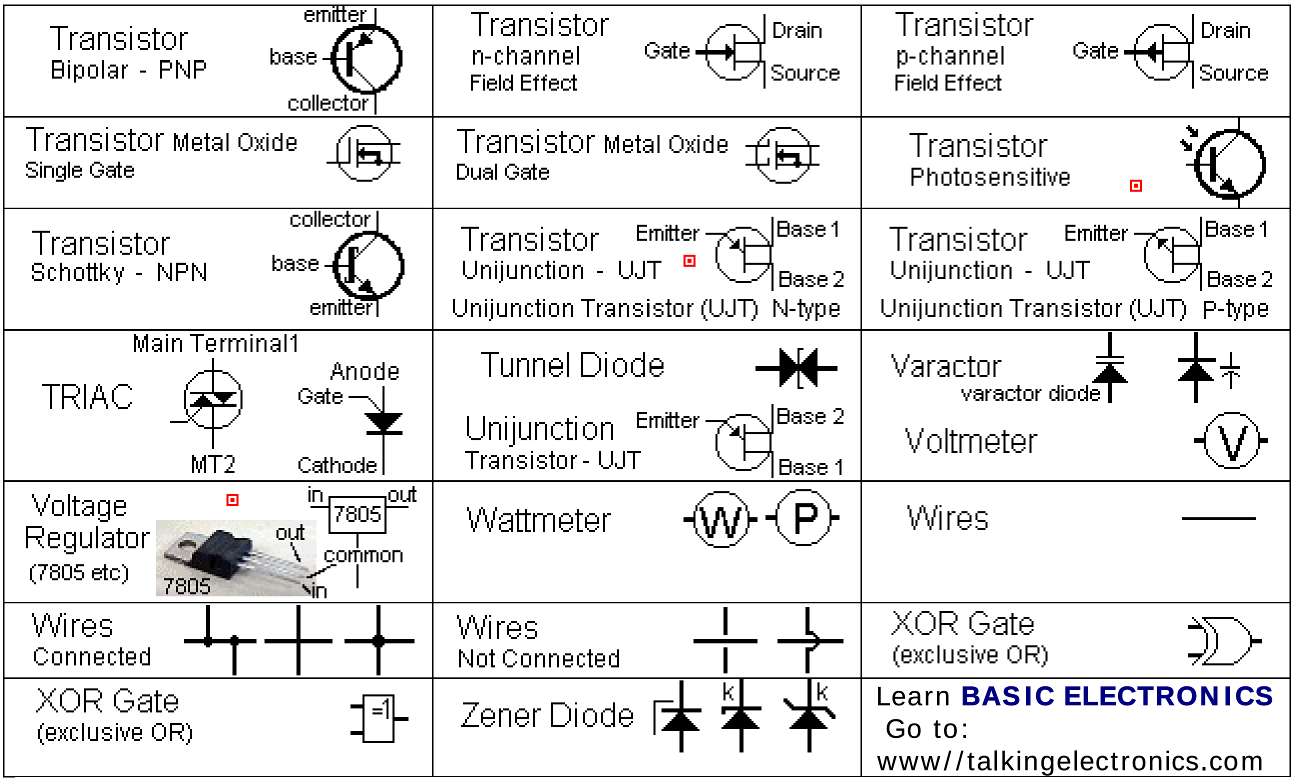
CONTENTS

CIRCUIT SYMBOLS by TALKING ELECTRONICS

AC current: voltage:	ALTERNISTOR TRIAC Main Terminal1 A TRIAC and 33 - 43v DIAC Gate Main Terminal 2	Ammeter (amp meter)
AND Gate	AND Gate	Antenna balanced
Antenna Loop, Shielded	Antenna Loop, Unshielded	Antenna unbalanced
Attenuator, fixed (see Resistor)	Attenuator, variable (see Resistor)	Battery
Bilateral Switch (DIAC)	Bridge Rectifier (Diode Bridge)	BUFFER (Amplifier Gate)
BUFFER (Amplifier Gate)	Buzzer	Capacitor feedthrough
Capacitor non-polarised	Capacitor polarised (see electrolytic)	Capacitor Variable
Cavity Resonator	Cell	Circuit Breaker
Coaxial Cable Connectors Plug (male) Jack (female) connected Plug (male) (female)	Crystal Microphone (Piezoelectric) Crystal Piezoelectric Darlington Transistor collector base emitter DC current: voltage:	Delay Line DIAC (Bilateral Switch) Diode k Diode - Gunn Diode - Light Emitting (LED)
Diode Photo Sensitive	Diode Photovoltaic λ	Diode Bridge (Bridge Rectifier)
Diode - Pin	Diode - Varactor	Diode - Zener
Earpiece (earphone, crystal earpiece)	Earth Ground	Electroluminescence el
Electret Microphone (Condenser mic) Electrolytic (Polarised Capacitor) alternate symbols: (positive on top)	Electrolytic - Tanatalum positive end black band or chamfer 10u tantalum Exclusive-OR Gate (XOR Gate)	Exclusive-OR Gate (XOR Gate) Field Effect Transistor (FET) n-channel also: N-Channel J FET Gate Drain Source
Field Effect Transistor (FET) p-channel also: P-Channel J FET Gate Drain Source	Flashing LED (Light Emitting Diode) (Indicates chip inside LED)	Fuse

Galvanometer G	Globe	Ground Chassis
Ground Earth Headphone	Heater (immersion heater) (cooker etc)	IC Integrated Circuit power ground
Inductor Air Core	Inductor Iron Core or ferrite core	Inductor Tapped
Inductor Variable	Integrated Circuit	Inverter (NOT Gate)
INVERTER (NOT Gate) 1	Jack Co-axial	Jack Phone (Phone Jack)
Jack Phone (Switched)	Jack Phone (3 conductor)	Key Telegraph (Morse Key)
Lamp Incandescent	Lamp - Neon	LASCR (Light Activated Silicon Controlled Rectifier)
LASER diode laser diode photo diode	LDR (Light Dependent Resistor) λ	Light Emitting Diode (LED)
Light Emitting Diode (LED - flashing) (Indicates chip inside LED)	Mercury Switch	Micro-amp meter (micro-ammeter) μA
Microphone (see Electret Mic)	Microphone (Crystal - piezoelectric)	Milliamp meter (milli-ammeter) mA
Motor MOT	NAND Gate	NAND Gate &
Nitinol wire "Muscle wire"	Negative Voltage Connection -	NOR Gate
NOR Gate ≥1	NOT Gate Inverter	NOT Gate Inverter 1
Ohm meter Ω	Operational Amplifier (Op Amp)	Optocoupler (Transistor output)
Opto Coupler (Opto-isolator) a k c e Photo-transistor output	Optocoupler (Darlington output)	Opto Coupler (Opto-isolator) a k c e TRIAC output
OR Gate	OR Gate ≥1	Oscilloscope see CRO
Outlet (Power Outlet)	Piezo Diaphragm	Photo Cell (photo sensitive resistor) λ
Photo Darlington Transistor	Photo Diode	Photo FET (Field Effect Transistor) Gate Drain Source
Photo Transistor	Photovoltaic Cell (Solar Cell) λ +	Piezo Tweeter (Piezo Speaker)

Positive Voltage Connection +	Potentiometer (variable resistor)	Programmable Unijunction Transistor PUT gate anode cathode
Rectifier Semiconductor k	Rectifier Silicon Controlled (SCR) Anode Gate Cathode	Reed Switch N
Relay - spst	Relay - spdt	Relay - dpst
Relay - dpdt	Resistor Fixed	Resistor Non Inductive
Resistor preset	Resistor variable	Resonator 3-pin
RFC Radio Frequency Choke	Rheostat (Variable Resistor)	Saturable Reactor
Schmitt Trigger (Inverter Gate) Shielding	Schottky Diode (also Shottky) Low forward voltage 0.3v Fast switching also called Schottky Barrier Diode k k	Shockley Diode 4-layer PNPN device Remains off until forward current reaches the forward break-over voltage. k
Signal Generator Silicon Controlled Rectifier (SCR) Anode Gate Cathode	Silicon Bilateral Switch (SBS) T_2 Terminal Gate T_1 Terminal e.g: BS08D T_2 G T_1	Silicon Unilateral Switch (SUS) Anode Gate Cathode(k) A G k
Solar Cell Spark Gap Speaker 8R Switch - mercury tilt switch Switch - spst Switch - spdt	Surface Mount c SOT-23 b e b c e b c e k A no connection k k & LED	Switch - process activated normally open: normally closed: Flow Level Pressure Temperature Switch - dpst
Switch - dpdt	Switch - push (Push Button)	Switch - push off (used in alarms etc)
Switch - Rotary	Test Point	Thermal Probe **NTC:** as temp rises, resistance decreases t° = ? NTC
Thermocouple Tilt switch mercury	Thyristors: Main Terminal1 Bilateral Switch Anode Gate Cathode MT2 Anode Gate Cathode **DIAC** **SCR** **TRIAC** **TRIAC**	Touch Sensor Transformer Air Core
Transformer Iron Core	Transformer (Tapped Primary/Sec)	Transistor Bipolar - NPN collector base emitter



Circuit Symbols

The list above covers almost every symbol you will find on an electronic circuit diagram. It allows you to identify a symbol and also draw circuits. It is a handy reference and has some symbols that have never had a symbol before, such as a Flashing LED and electroluminescence panel.

Once you have identified a symbol on a diagram you will need to refer to specification sheets to identify each lead on the actual component.

The symbol does not identify the actual pins on the device. It only shows the component in the circuit and how it is wired to the other components, such as input line, output, drive lines etc. You cannot relate the shape or size of the symbol with the component you have in your hand or on the circuit-board.

Sometimes a component is drawn with each pin in the same place as on the chip etc. But this is rarely the case.

Most often there is no relationship between the position of the lines on the circuit and the pins on the component.

That's what makes reading a circuit so complex.

This is very important to remember with transistors, voltage regulators, chips and so many other components as the position of the pins on the symbol are not in the same places as the pins on the component and sometimes the pins have different functions according to the manufacturer. Sometimes the pin numbering is different according to the component, such as positive and negative regulators.

You must to refer to the manufacturer's specification sheet to identify each pin, to be sure you have identified them correctly.

Colin Mitchell

1N4001 to 1N4007
Silicon Power Rectifiers

The following are subminiature general purpose power rectifiers for low power applications

Electrical Characteristics Specifications

Instantaneous Voltage Drop
@ forward current = 1 A 1.1V

Absolute Maximum Ratings

Peak Repetitive Reverse Voltage

1N4001	50V
1N4002	100V
1N4003	200V
1N4004	400V
1N4005	600V
1N4006	800V
1N4007	1000V

Maximum Full-Cycle Average Voltage Drop
@ Forward Current = 1 A 0.8V

Maximum
Reverse Current 0.03mA

RMS Reverse Voltage

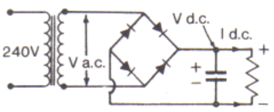
1N4001	35v
1N4002	70v
1N4003	140v
1N4004	280v
1N4005	420v
1N4006	560v
1N4007	700v

Their value will depend on the current and the degree of smoothing required. As a general guide, if the current being drawn from a supply is high, the size of the smoothing capacitor will need to be large (around 2500uF or larger) if the hum level is to be kept down to a respectable level.

It must also not be forgotten that all of these circuits are 'unregulated' i.e. as the load increases from zero to maximum the output voltage will drop due to the transformer voltage dropping under load and losses across the diodes - and the storage capacity of smoothing capacitors.

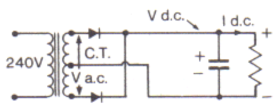
1) Full-Wave Bridge

DC Output Voltage
$= V_{AC} \times 1.41$ Peak



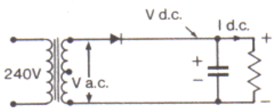
3) Full-Wave

DC Output Voltage
$= \frac{V_{AC}}{2} \times 1.41$ Peak



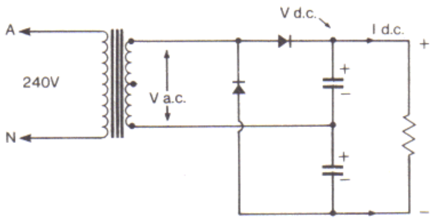
2) Half-Wave

DC Output Voltage
$= V_{AC} \times 1.41$ Peak



4) Voltage Doubler

DC Output Voltage
$= V_{AC} \times 2.82$ Peak



Example

Say for example we want a power supply to give 9V at 1 A. We could use a M21 55 transformer which is rated at 1 A. If we use a bridge rectifier and the 9V tapping the output voltage will be:-

V_{DC}= 1.41 XV_{AC} - 1.41 X9V = 12.69V Peak (9V at 1A load)

Loading and Nominal Voltage

One thing to be aware of with this type of power supply circuit is the voltages given by the formulas are nominal only. Because the actual output voltage of a transformer varies according to its load, the DC output of the power supply will also vary. As well as this, there is a voltage drop across the diodes which will vary according to load. If you need a very precise voltage, the best solution is to use one of the regulated power supply circuits shown in the zener Diode and Voltage Regulator sections of this ebook. You will see that most regulated circuits use one of the circuits above to produce unregulated DC, then regulate it to a consistent voltage that is independent of the load.

OA91 General purpose germanium signal diode

The OA91 is a small signal germanium point contact diode. It is suitable for a wide range of RF detector and small signal rectifying applications.

Specifications

I_P Forward current	50mA
V_R Reverse Voltage	90V Vp,
Forward voltage drop	
@ I_P = 10mA	1.05V
@I_F = 0.1mA	0.1V

Crystal Set

The crystal set consists of a tuned circuit which selects the wanted station or frequency, and a detector, which separates the information (music, speech etc.) from the radio transmission. The audio voltage produced is an exact replica of the sound from the radio station.
The detector diode rectifies the incoming signal, leaving a half wave radio signal which varies in amplitude with the audio signal. The fixed capacitor C_2 shorts out or 'bypasses' the RF signal, leaving only the audio.

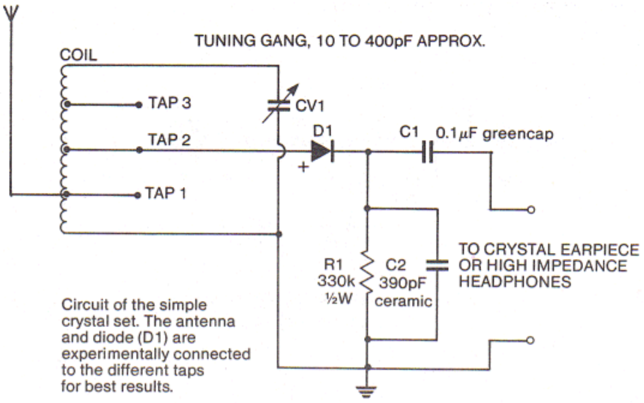
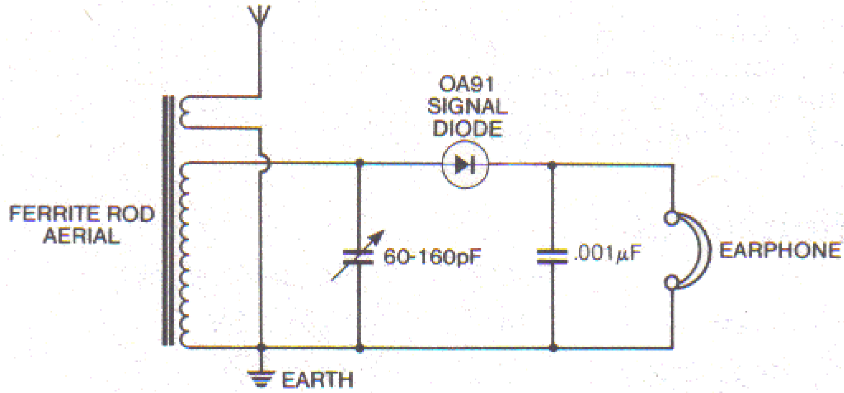
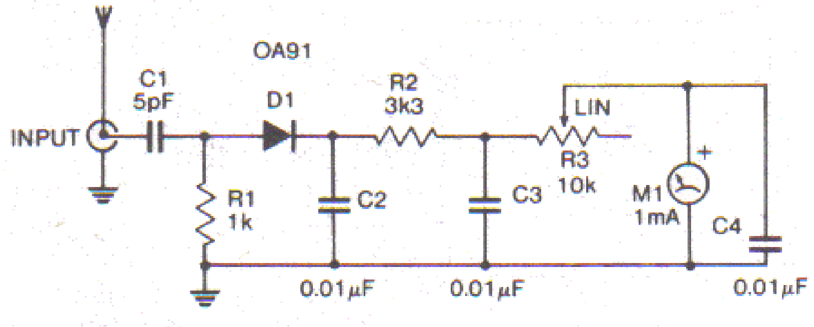


TABLE 1	NUMBER OF TURNS FOR WIRE GAUGE				
COIL DIA.	22 SWG	24 SWG	26 SWG	28 SWG	TAPS
30 mm				110	at ¼, ½ and
40 mm			96	90	¾ of the turns.
45 mm		88	80	70	You may tap
50 mm	82	72	68	60	every ten turns
55 mm	71	64	60	52	if you wish
65 mm	61	56	54	47	for more range
70 mm	54	52			of adjustment.

The circuit below is for a Crystal set using a readily available Ferrite rod and pre-wound aerial coil.



RF Monitor Meter



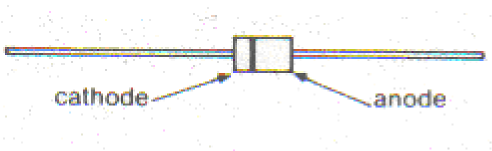
The circuit is an RF monitor meter suitable for measuring the strength of a signal from transmitters. You could use it to measure the effectiveness of different antennas for example. It works in much the same way as the crystal set, but without the tuned circuit. The meter M, will indicate the strength of the 'carrier'. Modulation of the carrier i.e. signal on the carrier, will cause the reading to vary. M, is not critical, and any meter of 1mA or better sensitivity will be suitable.

1N4148 Silicon Signal Diode

The 1N4148 is a general purpose signal diode suitable for a wide range of switching and low power rectifying purposes. It is equivalent to the 1N914.

Features

- Low Capacitance. 4pF at 0V
- High breakdown voltage. 100V

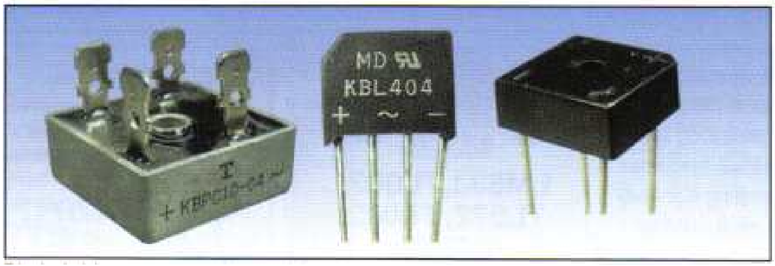


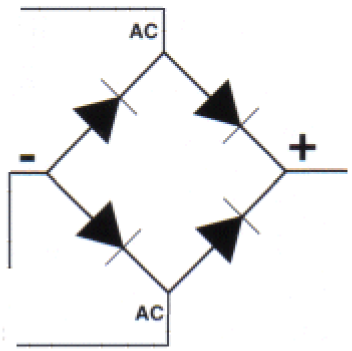
Specifications

Capacitance V_R=0, f= 1MHz	4pF
Reverse Recovery Time	4nsec
Rectification Efficiency 2.0V rms. f=100 MHz	

Absolute Maximum Ratings

Breakdown Voltage	100V
Working Inverse Voltage	75V
DC Forward Current	300mA
Maximum Total Dissipation at 25°C	500mW

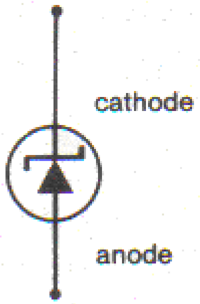




Diode bridges are a package of four diodes connected in a full wave bridge rectifier configuration. They can be encapsulated in plastic or steel/epoxy cases, and even DIL and surface mount packages for the smaller units. The square metal packages usually have one AC terminal marked, with the other terminal diagonally opposite it. The positive DC terminal is marked, with the negative terminal diagonally opposite it. Plastic square packages often have all terminal markings embossed in the package. In line plastic packages take up less PCB real estate while still maintaining a reasonable current capacity, and usually have their terminals marked with the AC connections being the inside two leads.

Zener Diodes

Zener diodes are used primarily as voltage references.
They are devices which maintain an almost constant voltage across them despite various changes in circuit conditions.



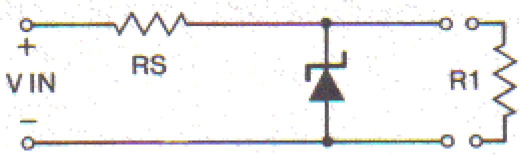
Zener symbol

Unlike conventional diodes, zener diodes are deliberately intended to be used with the anode connected to a negative potential (or 0v) and the cathode connected to the positive potential. When connected in this manner, zener diodes have a very high resistance below a certain critical voltage (called the zener voltage). If this voltage is exceeded, the resistance of the zener drops to a very low level.

When used in this region, essentially constant voltage will be maintained across the Zener, despite quite large changes in the applied currents. This is illustrated graphically in the figure below.
It can be seen that beyond the zener voltage, the reverse voltage remains practically constant despite changes in reverse current. Because of this, Zener diodes may be used to provide a constant voltage drop, or reference voltage.
The actual voltage available from a zener diode is temperature dependent.

The Basic Circuit

The Basic Voltage regulator circuit is shown below. It uses only one resistor and one zener diode. This is called a SHUNT REGULATOR. See SERIES REGULATOR below.



If the Zener diode is rated at 5.6V and the applied voltage is 8.0V, then with no load applied, the output voltage across R1 will be 5.6V and the remaining 2.4V will be dropped across R_s, If the input voltage is changed to 9.0V, then the voltage across the Zener will remain at 5.6V. In practice, the voltage across the Zener will rise slightly due to the 'dynamic resistance' of the zener.
The resistor R1 represents an external load. When this load is connected, some of the current flowing through the zener will now pass through the load. The series resistor R_s is selected so that the minimum current passing through the zener is not less than that required for stable regulation. It is also necessary to ensure that the value of R_s is such that the current flow through the zener cannot exceed its specified power rating. This can be calculated by multiplying the zener voltage by the zener current. The design procedure is as follows:-
1) Specify the maximum and minimum load current, say 0mA and 10mA.
2) Specify the maximum and minimum supply voltages (say 12v) but ensure that the minimum supply voltage is always at least 1.5v higher than the zener voltage being used.
3) In the circuit shown the minimum zener current is 100µA. Thus the maximum zener current (which occurs when there is no load connected) is 10ma plus 100µA equals 10.1mA.
4) The series resistor must conduct 10.1mA at the lowest input supply voltage, so the minimum voltage drop across R_s will be 1.5v. Thus the value of R_s will be:-

$1.5v / 10.1X10^{-3}$ = 148.5 ohms

This could be changed to the nearest preferred value of 150 ohms.

5) At the maximum supply voltage (12v) the voltage across R_s is equal to the zener current times the series resistor.

$$I_z \text{ (zener current)} = \frac{(12 - 5.6)\ V}{150 \text{ ohms}} = 42.6mA$$

This is the maximum (worst case) zener current. To work out the resulting power dissipation, we multiply this current by the zener voltage. In this example this works out at:-

$$I_zV_z = 42.6 \times 5.6 = 238mW$$

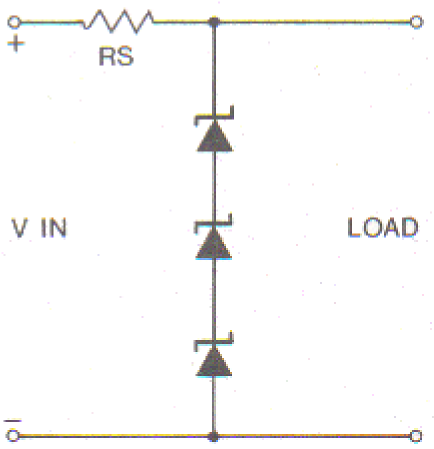
Any zener over this in power rating would be suitable in this circuit.

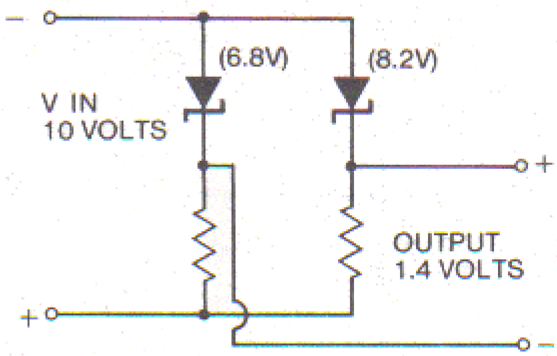
Temperature Drift in Zeners

Typical zener diodes drift in their voltage at about +0.1%/°C at the higher voltages. At lower voltages this goes negative reaching -0.04%/°C at around 3.5v.
This may be made use of in temperature sensing devices. The circuit below shows how a bridge consisting of two similar zener diodes and two resistors can indicate temperature differences when one zener is held at standard temperature and the other is subjected to the conditions to be monitored. If a 10v zener is used, it will have a temperature coefficient of +0.07%/°C giving a change of 7millivolts per degree C.

Non Standard Voltages

Non standard voltages can be obtained by connecting zener diodes in series. The diodes need not have the same voltages since this arrangement is self equalizing.

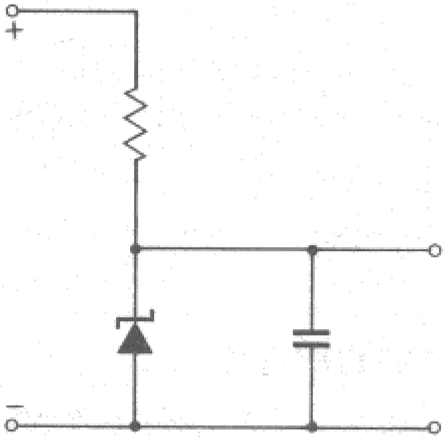




It may also be necessary at times to provide a regulated voltage lower than that normally available from a zener diode. These voltages may be obtained by using the difference between two pairs of zeners. This is shown in the circuit below. As a bonus, the temperature compensation of this circuit is excellent, since both zeners tend to drift in the same direction, maintaining the voltage difference.

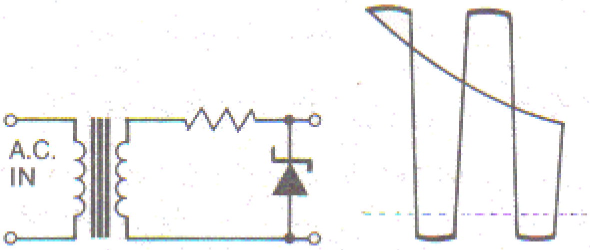
Zener Noise

Zener diodes generate noise voltages. These may vary between 10µV and 1mV depending on zener voltage and rating. This noise is easily suppressed by placing a 0.01 to 0.1µF capacitor across it. This reduces the noise voltage by a factor of at least 10.



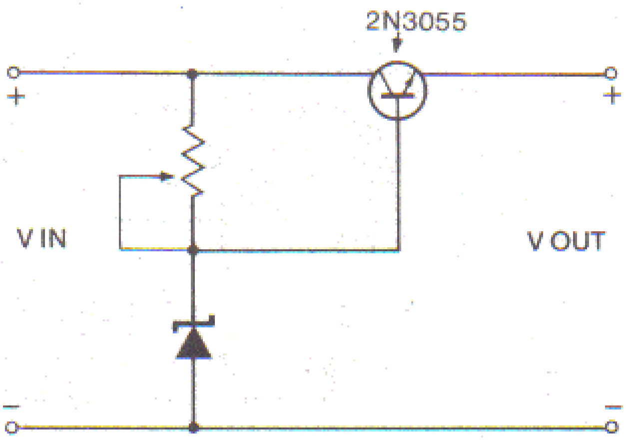
Zener Diode as a Calibration Signal

When supplied with alternating current, the zener diode will limit both the negative and positive halves of the AC cycle. The waveform will be asymmetrical, since the zener will limit almost immediately in one direction, but will not limit until its zener voltage in the other direction.



Increased Power Handling

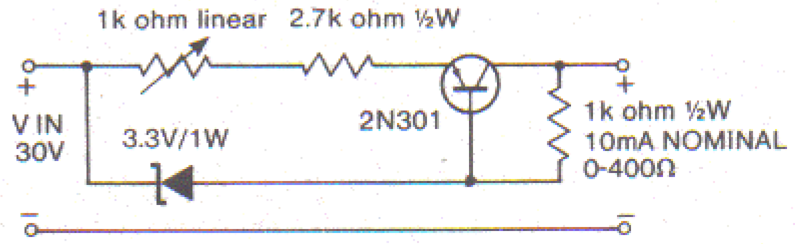
Although zeners can be paralleled for higher power operation, it is usually a better idea to use a series transistor with a zener reference. This configuration improves the power handling and also the regulation of the circuit by a factor equal to the current gain of the transistor.



The output voltage of this circuit will be equal to the zener voltage minus the base-emitter voltage of the transistor (approx. 0.7V).
Output Voltage = Zener Voltage - 0.7V.

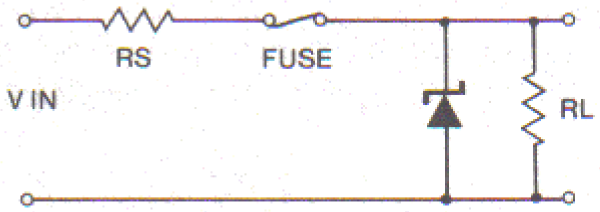
Constant Current Regulation

This simple circuit maintains a constant current (within approx 10%).



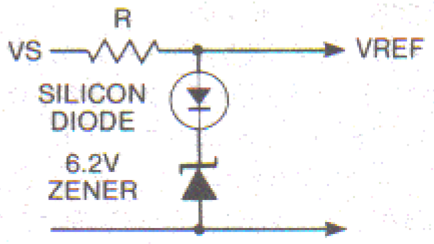
Over-voltage Protection

The circuit below uses the zener as a 'fuseblower'. The zener is selected so that under normal operation it is not conducting. If the circuit develops a fault and the power supply voltage rises above the zener voltage, the zener will come 'on' and draw a heavy current, blowing the fuse.



Improving temperature stability

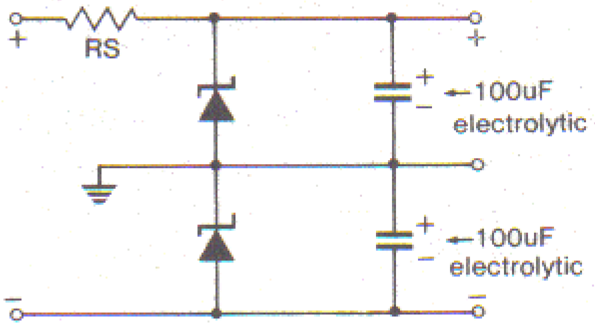
If better temperature stability is required than can be obtained with a single zener, a good trick is to use an ordinary forward biased silicon diode. This makes use of the fact that the forward voltage temperature coefficient of a silicon diode is approximately -2mV/°C. The temperature coefficient of the silicon diode and the zener diode cancel out, giving an almost temperature independent voltage reference. The use of the forward biased diode also allows 'trimming' of zeners to voltages other than the preferred value available. A silicon diode when forward biased will have a voltage drop of 0.7v. When put in series with a zener it will increase the reference by this much. Thus a 6.2v zener plus a silicon diode will give a voltage of 6.9v.

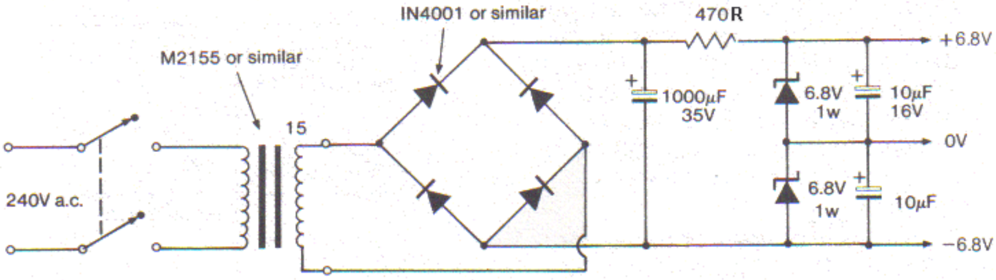


Dual Voltage Power Supply

The circuit below uses zener diodes to give a split or dual power supply which is ideal for running ICs such as op-amps. The power input only needs to be an unregulated single rail DC source. When selecting R_s it should be remembered that the zener is the sum of the voltage of the two zeners.

These two circuits show typical use of zeners in power supply circuits. The circuit below is designed to give increased current capacity. It will supply up to 1A with suitable heatsinking of the transistors.





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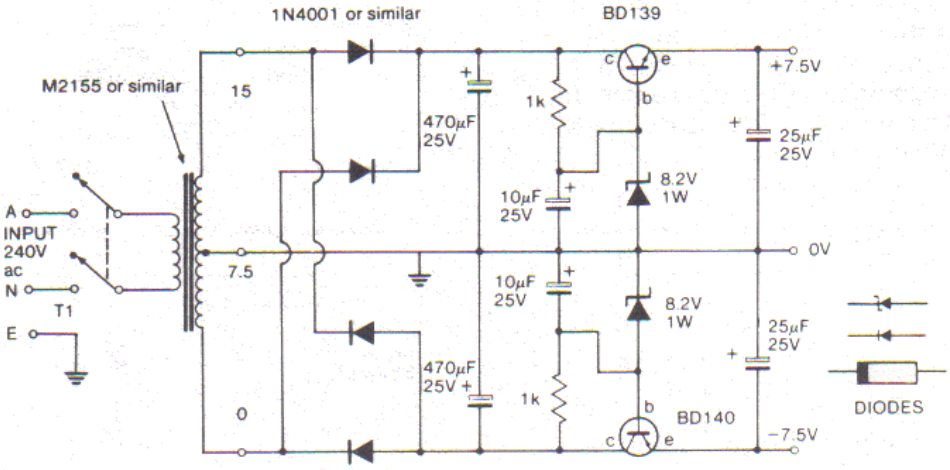
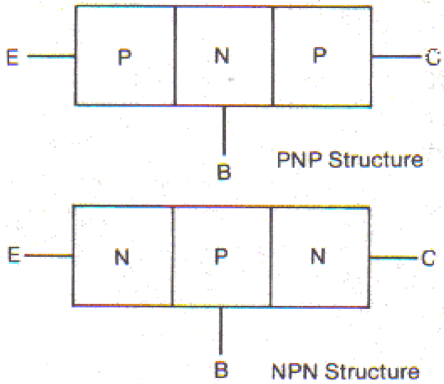
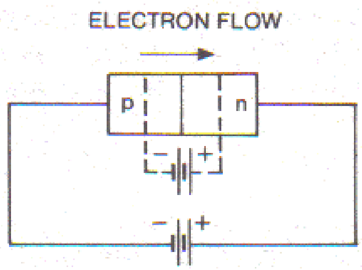


Semiconductor Devices

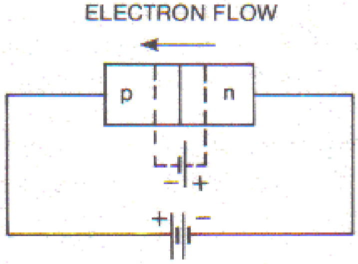
The simplest type of semiconductor device is the diode. It has two electrodes, a cathode and an anode. Il is formed from a junction of P and N type silicon. As shown below, when the diode is forward biased, by applying a negative voltage to the cathode (the N type silicon) and a positive voltage to the anode (the P type silicon) the diode conducts and has a very low resistance. If the voltage connections are reversed, the diode is said to be reversed biased and has a very high resistance.



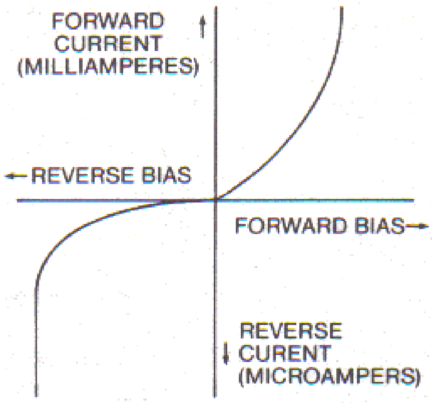
Electron current flow in biased p-n junctions.



(a) REVERSE BIAS

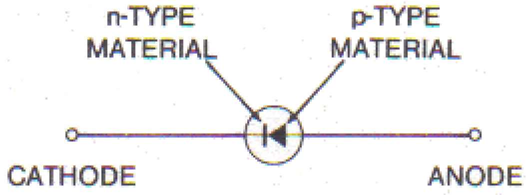


(b) FORWARD BIAS



Voltage-current characteristic for a p-n junction.

If another layer is added to the semiconductor junction, the resulting device becomes a bipolar transistor. The three layers of the device are the emitter, the collector and the base. In normal operation, the emitter to base junction is forward biased and the collector to base junction in the reverse direction.
There are two types of transistor, NPN and PNP. The names relate to the 'sandwich' structure of the two types of transistor. They are shown below. For practical purposes, the important difference between the two types of transistor is that in NPN transistors the current flows from emitter to collector. In PNP transistors the electrons flow from collector to emitter.



Schematic symbol for a solid-state diode.

Simple diode rectifying circuit.

Bipolar Transistors

Bipolar Transistors are current amplifying devices. When a small signal current is applied at the input terminal (the base) of the bipolar transistor, an amplified reproduction of this signal appears at the output terminals (the collector).

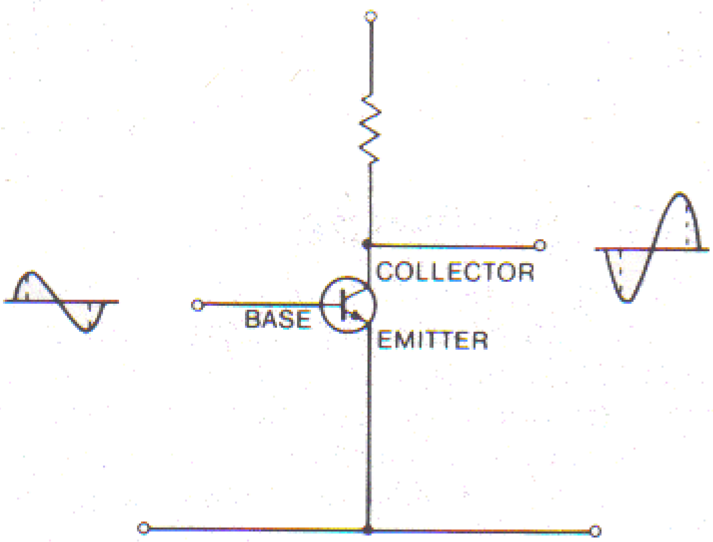
(a) FUNCTIONAL DIAGRAM (b) n-p-n TRANSISTOR (c) p-n-p TRANSISTOR

Functional diagram and schematic symbols for bipolar transistors.

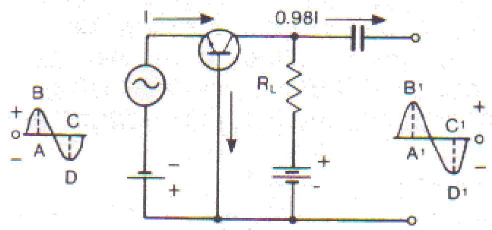
There are 3 useful way of connecting the input signal for amplification.

Common Base Mode

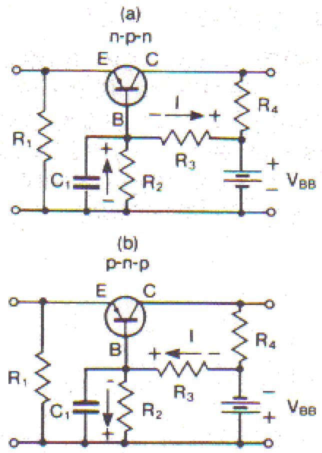
In this mode, the signal is introduced into the emitter-base circuit (Thus the base element is common to both the input and output circuits. In this mode, the input impedance is low (i.e. it puts a heavy load on the signal source). The output impedance is fairly high. This type of circuit gives voltage gain and slightly less than unity current gain.



Commonly used as an impedance converter.



Common-base circuit configuration

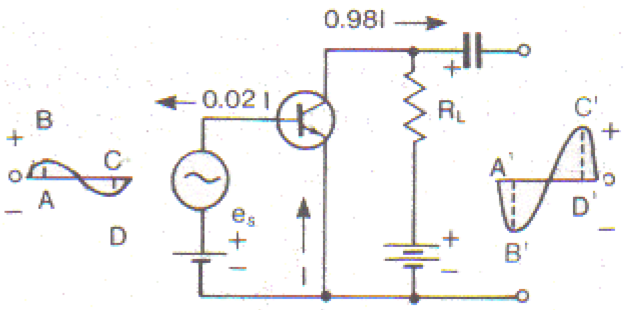


Biasing network for common-base circuit

Common Emitter Mode

In this configuration, the signal is introduced into the base-emitter circuit. This arrangement has moderate input and output impedance. It gives both current and voltage gain. Current gain is measured by comparing the base current and the collector current and so is equivalent to H_{FE} A very small change in base current produces a relatively large change in collector current. Depending on the type of transistor this will vary from 5-600.

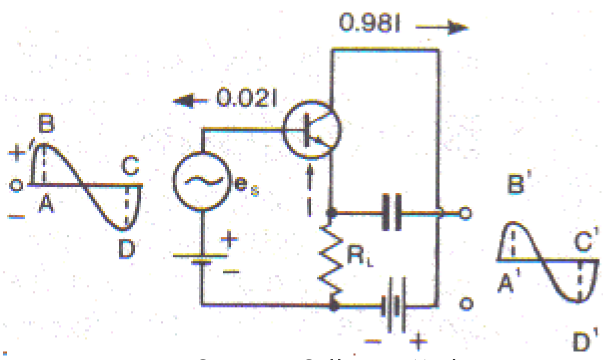
This is the most commonly used circuit, very often found in audio amplifiers. For an explanation of H_{FE} see definition below.



Common-emitter circuit configuration

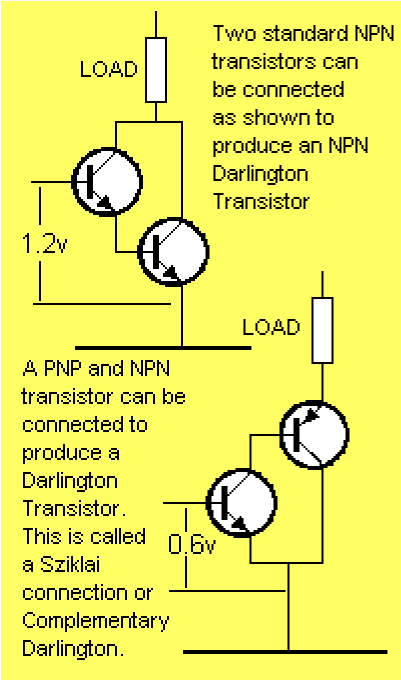
Common Collector Mode

In this configuration, the signal is introduced into the base/collector circuit and is 'extracted' from the emitter/collector circuit. The input impedance of this arrangement is high and the output impedance is low. The voltage gain is less than unity while the current gain is high. This configuration is used as an impedance matching device. Commonly called an emitter follower, it is also often used as a current amplifier in power supplies.



Common Collector Mode

Darlington Pair



The Darlington Pair uses a pair of transistors coupled together as an emitter follower so that the emitter current of the first transistor flows through the base/emitter junction of the second transistor. The resulting current gain of the transistor pair is found by multiplying the current gain of the transistors together. The resulting current gain is very high and the input impedance of such a stage is very high.

Biasing Arrangements

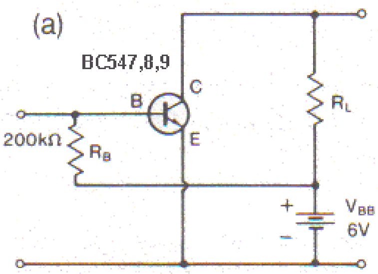
For linear amplification as opposed to switching applications, the 'operating point' of the transistor must be set so as to minimize distortion. The simplest of biasing arrangement is shown below. The base resistor R_B is selected to provide the desired base current, which is 27µA in the example shown. This base current turns the transistor 'on' and establishes the collector current.
In the circuit below (a):

$$R_B = V_{supply} - V_{BE} / I_B$$

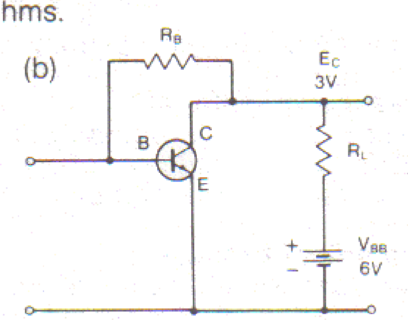
V_{BE}, the base emitter voltage is 0.6V for silicon transistors and 0.2V for germanium transistors. Thus:–

$$R_B = \frac{6 - 0.6V}{27 \times 10^{-6}}$$

$$= 200k \text{ ohms.}$$



"Fixed-bias" arrangement for common-emitter circuit.



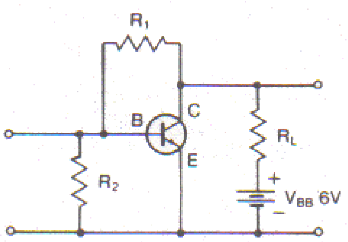
"Self-bias" arrangement for common-emitter circuit.

This arrangement is sensitive to temperature and varying gains of transistors. A better arrangement is shown above (b). This stabilizes the operating point of the transistor because an increase in collector current drops the collector voltage and thus decreases the base bias.

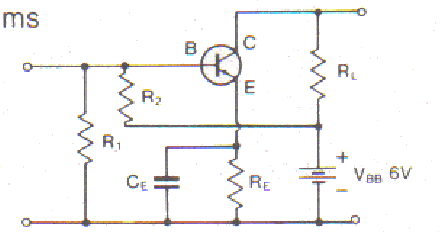
$$R_B = \frac{V_{CE} - V_{BE}}{I_B}$$

$$= \frac{3 - 0.6V}{27 \times 10^{-6}}$$

$$= 90k \text{ ohms}$$



Bias network using voltage-divider arrangement for increased stability.



Bias network using emitter stabilizing resistor.

Definitions

Alpha (a) Gain

In the common base mode, the emitter is the input electrode and the collector is the output electrode. The alpha is the ratio of the collector current l_c to the emitter current I_E. It is always less than 1.

Beta current gain (h_{FE})

In the common emitter mode, the base is the input terminal and the collector is the output terminal. The beta is the ratio of the collector current l_c to the base current I_B.

Gain Bandwidth Product (f_{hfe})

This is the frequency at which the alpha or beta (according to the type of circuit) drops to 0.707 times its 1 kHz value.

Transition Frequency (f_T)

The frequency at which the small-signal forward current transfer ratio (common-emitter) falls to unity.

Breakdown voltage

This defines the voltage between two electrodes at which the current rises rapidly. The breakdown voltage may be specified with the third electrode open, shorted or biased to another electrode.

Secondary Breakdown

High voltages and currents passing through a transistor cause current to be concentrated or focused on a very small area of the transistor chip causing localized overheating. This is important in power transistors which are often designed to minimize this effect.

Saturation Voltage (Vce_{sat})

For a given base current, the collector-emitter saturation voltage is the potential across this junction while the transistor is in conduction. A further increase in the bias does not increase the collector current. Saturation voltage is very important in switching and power transistors. It is usually in the order of 0.1v to 1.0v

Safe-operating-area

Power transistors are often required to work at high currents and high voltages simultaneously. This ability is shown in a safe operating area curve.

P_{TOT}

The total package power dissipation

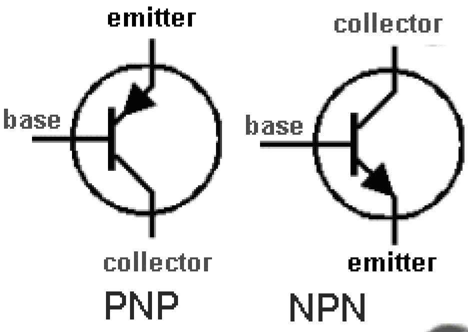
V_{CBO}

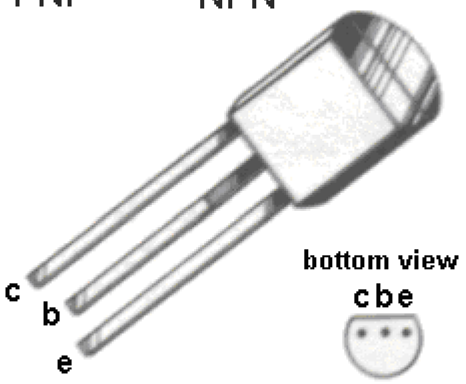
The dc voltage between the collector terminal and the base terminal when the emitter terminal is open-circuited.

V_{CEO}

The dc voltage between the collector terminal and the emitter terminal when the base terminal is open-circuited.

BC547-9 (BC107-9) NPN BC557-9 (BC557-9) PNP





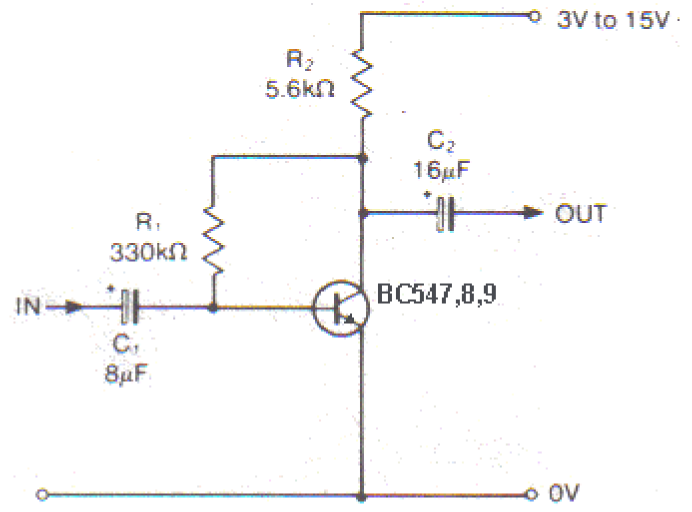
Low frequency, general purpose small signal transistors widely used in audio, switching and television circuits. The BC547-9 series and BC557-9 series are functionally identical to the common BC107-9 series.
All have a maximum power dissipation of 500mW. They have essentially similar specifications and can generally be substituted for one another (within the PNP and NPN groups of three each). All devices are housed in standard TO-92 plastic packages.

Specifications

NPN	**BC547**	**BC548**	**BC549**
VCBO	50v	30v	30v
V_{ct}o	45v	30v	30v
l_c	100mA	100mA	100mA
P_{totl}	500mW	500mW	500mW
h_{FE} min-max at I_0 2mA	110 - 800	110 - 800	200 - 800
f_T typical	300MHz	300MHz	300MHz
V_{CEsat} (max) at l_c 100mA/l_B 5mA	600mV	600mV	600mV

PNP	**BC557**	**BC558**	**BC559**
VCBO	50v	30v	30v
VCEO	45v	30v	30v
l_c	100mA	100mA	100mA
$P_{,ot}$ 500mW		500mW	500mW
h_{FE} min-max at l_c 2mA	75 - 475	75 - 475	125 - 475
f_T typical	150MHz	150MHz	150MHz
V_{CEsat} (max) at l_c 100mA/l_B 5mA	600mV	600mV	600mV

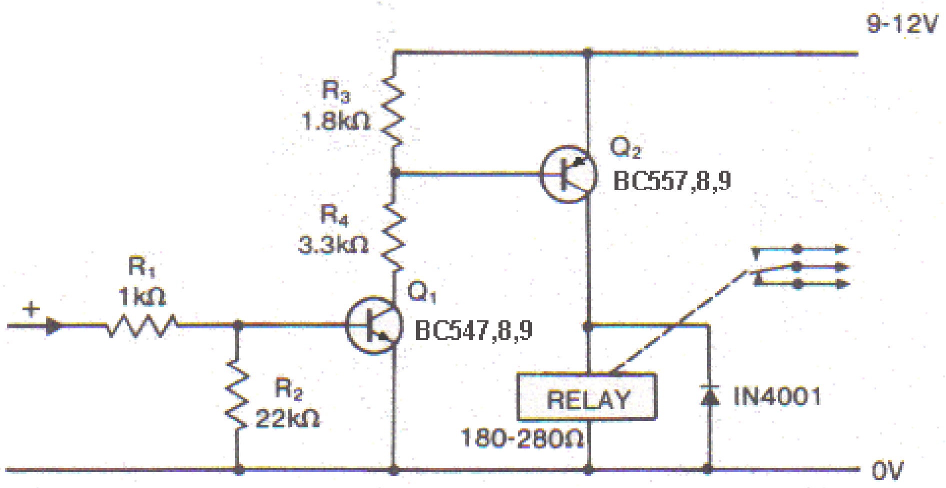
A Simple Amplifier



This circuit will operate on any supply from 3v to 15v. Using a 9v supply, the circuit gives a voltage gain of 46dB (200 times), frequency response within 3dB from 30Hz to 100kHz, input impedance of 1.5k ohms and an output impedance of 5.6k ohms. The base bias resistor R_1 gives sufficient negative feedback to compensate for the large variation of h_{FE} values in individual transistors and for variations in supply voltage.

Relay driver

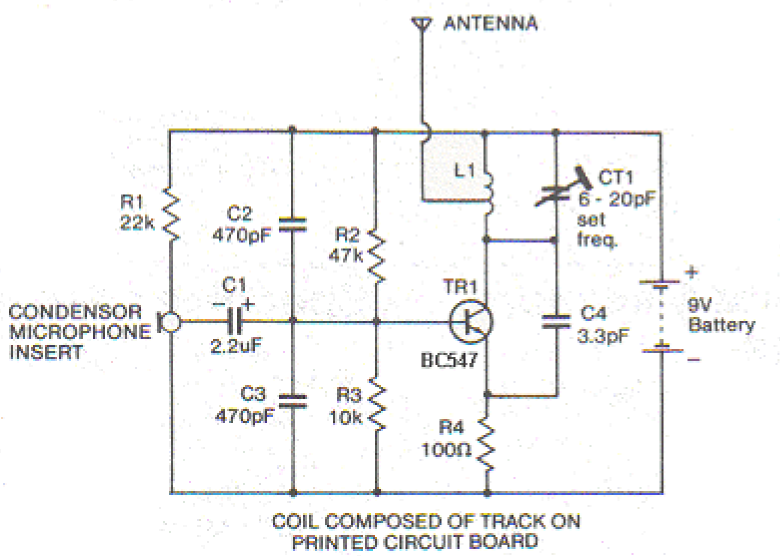
This simple circuit increases the sensitivity of a relay so that it will trigger at 700mV at 40uA. Any relay with an operating current of less than 60mA and operating voltage of less than 12v is suitable. The circuit's supply rail should be at least 3v higher than the operating voltage of the relay.



The circuit will work with any relay with a coil resistance higher than 180 ohms and a pull in voltage of less than 12v.

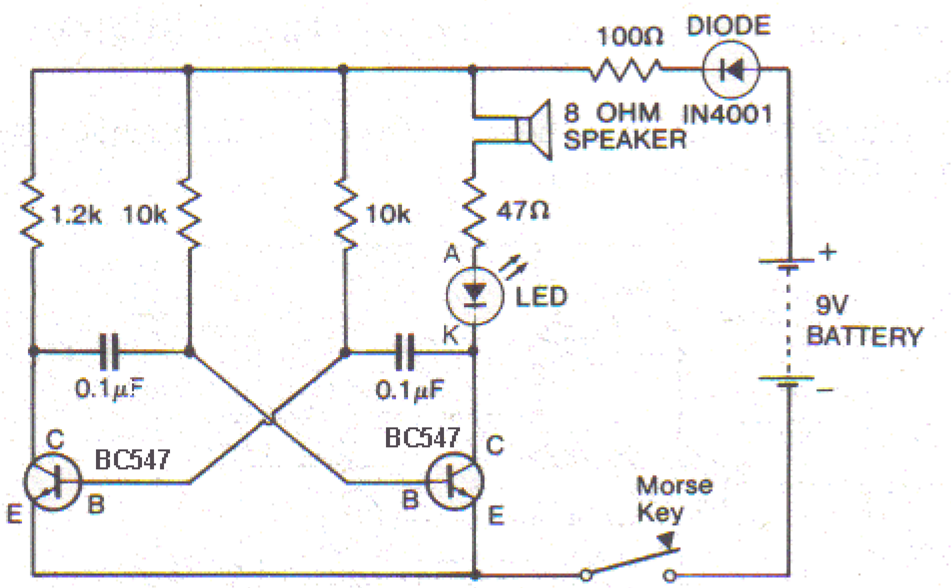
FM transmitter

This circuit, is about as simple as a transmitter can get. The coil is etched onto the printed circuit board, but can be easily substituted by 6 turns on a 4mm diameter former.



Multivibrator- Morse Code Generator

This circuit is an astable multivibrator or square-wave generator. The circuit is suitable as a morse code generator. The frequency of operation can be raised by making the value of the capacitors smaller. The speaker can be any general purpose 8 ohm type.

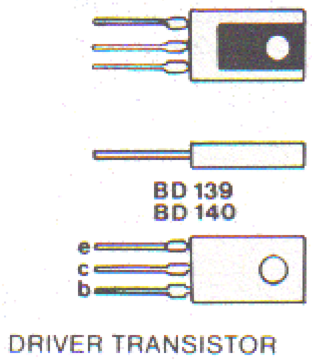


BD139/140 Driver Transistors

BD139/140 are complementary silicon driver transistors designed for audio and switching applications. They come in TO-126 plastic cases. The BD139 is an NPN device and the BD140 is PNP.

Features

- High gain (h_{FE}40-250)
- High f_T (250MHz for BD139, 75MHz for BD140)



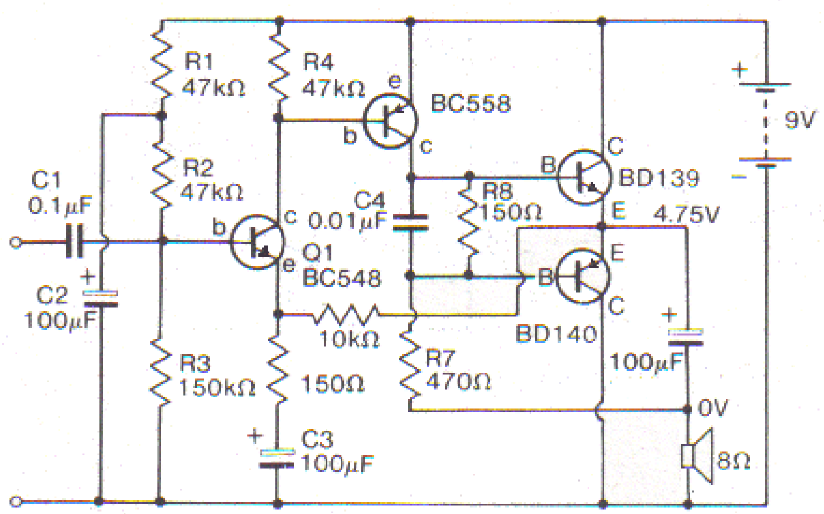
Absolute Maximum Ratings

Collector-Emitter Voltage (V_{CEO})
BD139 80V
BD140 80V
Collector-Base Voltage (V_{CBS})
BD139 100V
BD140 100V
Collector Current Continuous (Ic)
BD139/140 1A
Total Device Dissipation (Ptot)
BD139/140 8W

Specifications

DC Current gain (h_{FF})
@ I_c = 150mA 40-250 (BD139/140)
f_T(MHz)
BD139 250MHz
BD140 75MHz
Collector-Emitter Saturation Voltage (V_{CEsat})
@ I_c = 500mA 0.5V
(BD139/140) I_B = 50mA

Basic Amplifier



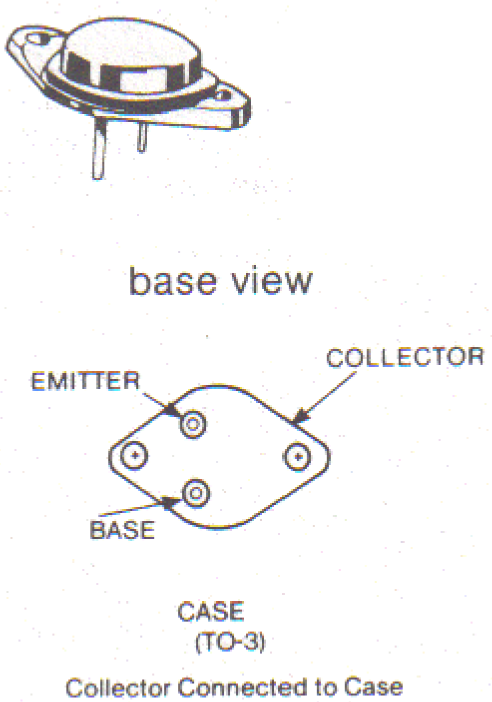
The circuit is for a low power amplifier using a BD139/140 pair in the output stage.
The amplifier has a gain of 66.
It needs 10OmV input for full output,
which is approximately 500mW into 8 ohms.

2N3055 Power Transistor

The 2N3055 is a medium speed NPN Silicon Power Transistor designed for general purpose switching and amplifier applications.

Features

- DC current Gain (h_{FE}) = 20-70 @ I_c = 4.0A
- Collector-Emitter Saturation Voltage = 1.0V @ I_c = 4.0A



Absolute Maximum Ratings

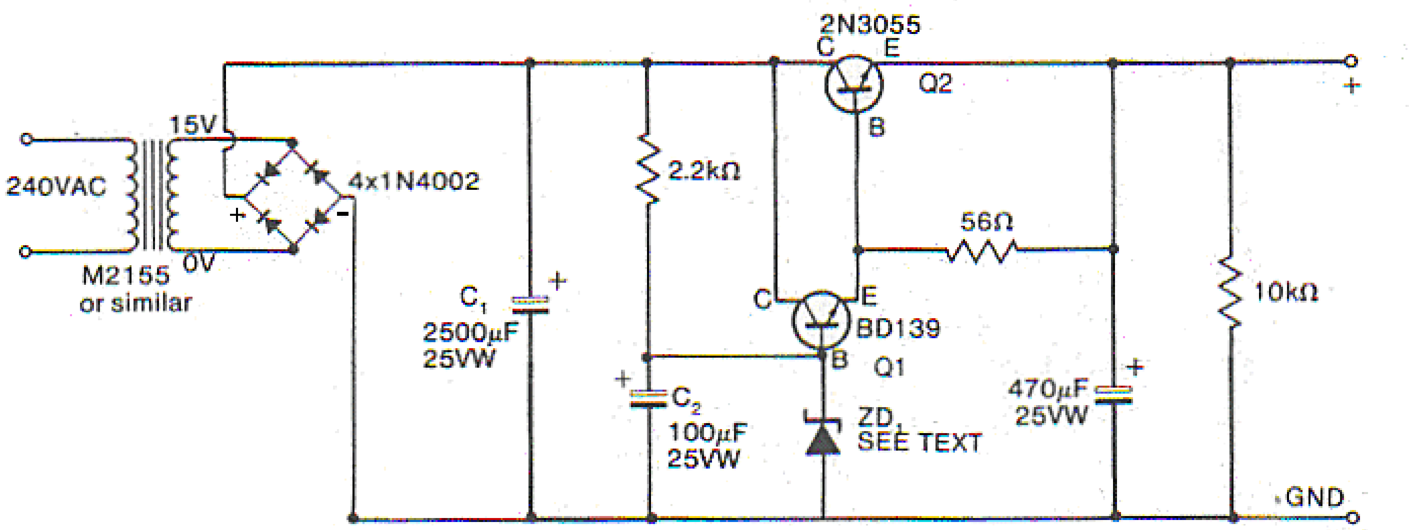
Collector-Emitter Voltage (V_{CEO})	60v
Collector-Base Voltage (V_{CBO})	100v
Emitter-Base Voltage (V_{EB})	7.0v
Collector Current Continuous (I_c)	15A
Base Current Continuous (I_B)	7A
Total Device Dissipation (P_{tot})	115W

Specifications

Collector- Emitter Leakage Current	
(V_{CE} = 30V, I_B = 0)	0.7mA
DC Current Gain (H_{FE})	
I_c = 4.0A V_{CE} = 4.0V	20-70
I_c = 10.0A V_{CE} = 4.0V	5 (Minimum)
Collector-Emitter Saturation Voltage	
I_C = 4.0A I_B = 0.4A	1.1v
I_c = 10.0A I_B = 0.4A	8.0V
Ft @ I_C = 3.3A	0.8MHz

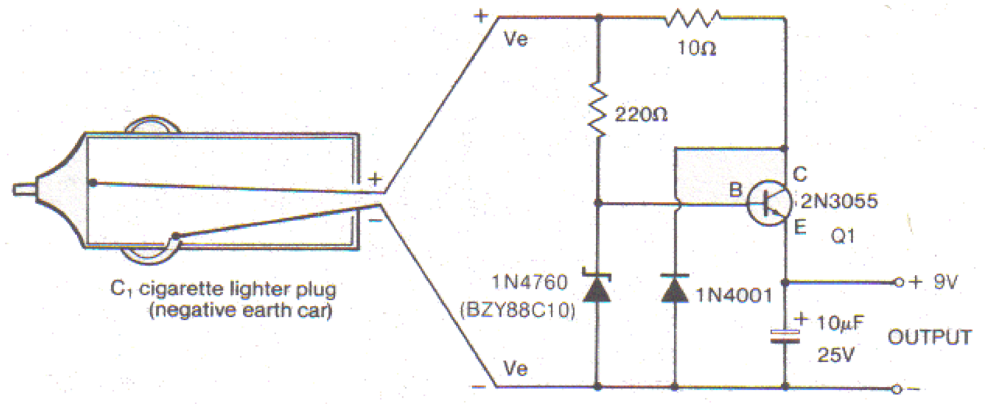
Low Ripple Regulated Power Supply

The excellent characteristics of the 2N3055 at high currents (high h_{FE} and low collector-emitter saturation voltage) makes it ideal as a series regulator transistor in regulated power supplies. The power supply circuit shown below can be used when high current with low ripple is required. Q_1 and Q_2 form a high power Darlington. ZD_1 and R_1 provide a reference voltage at the base of Q_1 The voltage output will be:- V_{OUT} = Zener Voltage - 1.2v



Car Voltage Converter for radios and cassettes

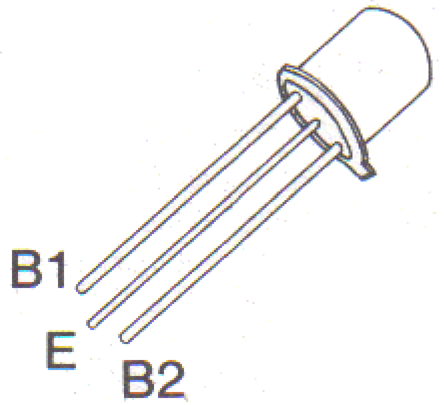
This circuit is suitable for dropping a 12v car battery to the correct voltage to run portable cassette players/radios etc. Using a 2N3055 might seem like a bit of an overkill but they are cheap. The output voltage will be 0.7v lower than the zener voltage, due to the voltage drop across the base-emitter junction of the 2N3055. The 10 ohm series resistor stops excessive current being drawn in the case of a short. The diode (1N4001) protects the transistor in case of reverse voltage being applied.



The output will drive transistor radios, cassette players etc. If the current drain is over 500mA, it is a good idea to put a heat sink on Q_1. Mounting the converter in a metal box with Q_1 on the lid (but insulated from it with a mica washer) will act as a good heatsink.

2N2646 Unijunction transistor

The 2N2646 is intended for general and industrial triggering and oscillator circuits where circuit economy is of primary importance. lt is a high speed switching device with a low saturation voltage.



Absolute maximum ratings

Power Dissipation	300mW
RMS Emitter Current	50mA
Peak Emitter Current	
(Capacitor discharge <10µF)	2A
Emitter Reverse Voltage	30V
Interbase Voltage	35V

Specifications

Intrinsic Standoff Ratio (V_{BB} = 10v)	ή	0.69
Interbase Resistance (V_{BB} = 3v, I_e = 0)	R_{BB0}	6.7
Emitter Saturation Voltage (V_{BB} = 10v, I_E = 50mA)	$V_{E(sat)}$	2
Emitter Reverse Current (V_{B2E} = 30V I_{B1} = 0)	I_{E0}	.001
Peak Point Emitter Current (V_{BB} = 25v)	I_P	0.8
Valley Point Current (V_{BB} = 20v R_{B2} = 100R)	I_V	5
Base-One Peak Pulse Voltage	V_{0B1}	8.5

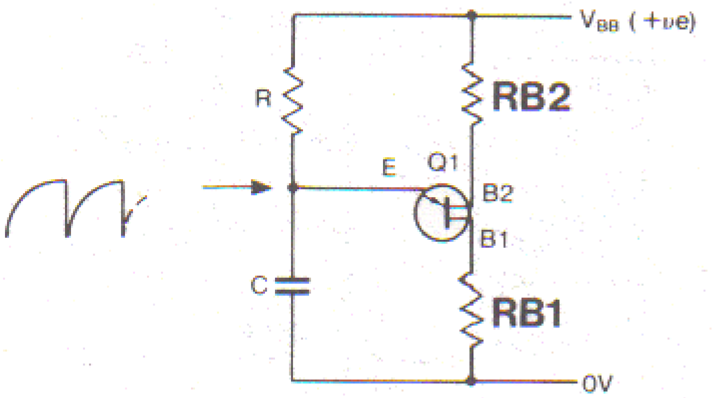
Basic Theory

The unijunction transistor (UJT) has 3 terminals: Emitter (E). Base-one (B_1 and Base-two (B_2). Between B, and B_2 the UJT has a resistance of from 4.7k to 9.1k.

In operation the UJT emitter voltage V_E is lower than the emitter peak voltage V_I. The emitter will be reverse biased and only a small leakage current will flow. When V_E equals V_I the emitter current will increase enormously. At the same time the emitter-B_1 resistance will fail to a very low level.

Basic UJT Pulse Trigger Circuit

This is a basic relaxation oscillator. C charges through R, until the emitter reaches V_P at which time the UJT turns on and discharges C_1 via R_{B1}. When the emitter has dropped to approximately 2v, the emitter stops conducting and the cycle starts again.

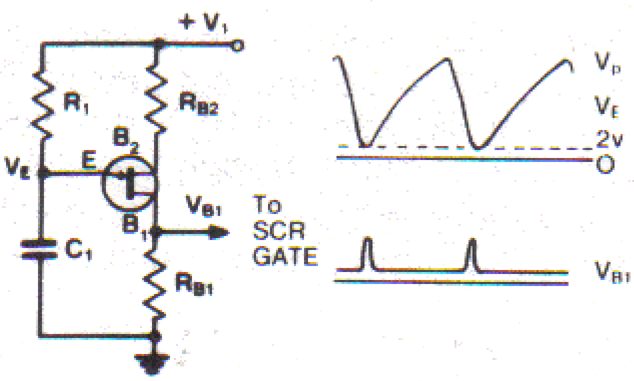


BASIC RELAXATION OSCILLATOR

The frequency of operation (f) $= \frac{1}{RC}$

for example: R = 10k, C = 1μF, $f = \frac{1}{10^4 \times 10^{-6}} = 100Hz$

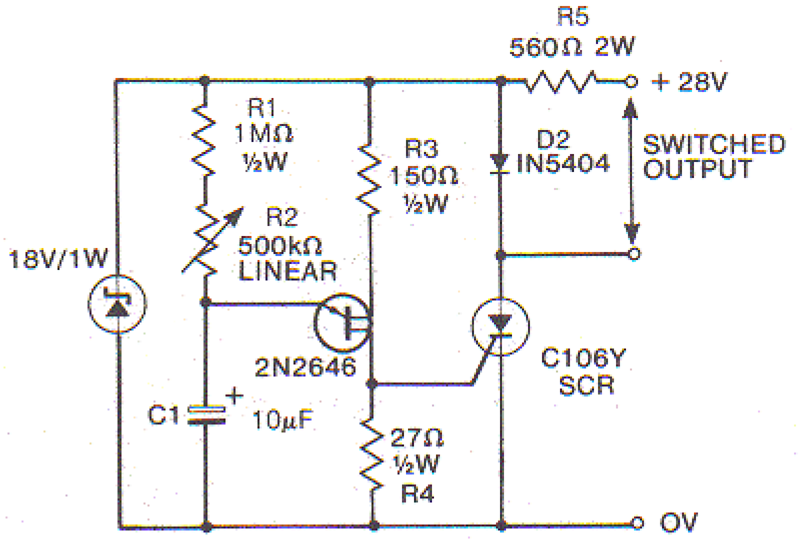
The design of the UJT trigger is very broad.
RB_1 is limited to values below 100 ohms for most applications. R_1 should be a value between 3k and 3M. Supply voltage can be from 10 to 35v.
If the circuit is being used to trigger an SCR, RB_1 must be low enough to prevent DC voltage at the gate from exceeding the maximum voltage that will not trigger the SCR. In practice, keep R_B, below 50 ohms.
The 2N2646 is specifically designed for SCR trigger circuits. R_{B2} is typically 100 ohms.



BASIC UNIJUNCTION TRANSISTOR RELAXATION OSCILLATOR-TRIGGER CIRCUIT WITH TYPICAL WAVEFORMS

UJT/SCR Time Delay Relay

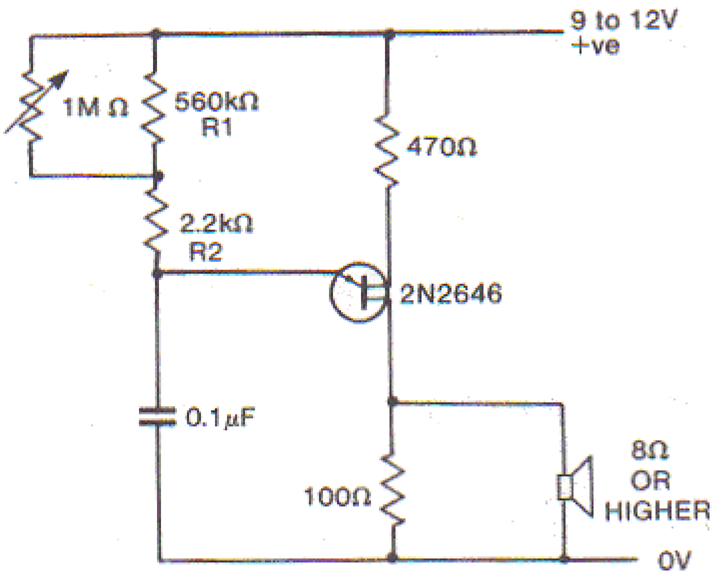
This circuit provides an efficient, high power and accurate time delay circuit. The SCR should be selected to suit the application. R_5 and the zener diode maintain a stable supply for the UJT.



Initially the SCR is off. The timing sequence is started by shorting out C1. C1 then charges through R1 and R2 until the UJT triggers, developing a pulse across R4 which turns on the SCR. Holding current for the SCR is supplied by current through R5 and D2. When the SCR triggers, it pulls the voltage across the UJT to <2 volts. This discharges C1.
The load this circuit will drive depends on the SCR used. A suitable type would be a C106Y. This has a maximum current rating of 4A. This would be enough to drive a relay (even one with a low coil resistance), globes or an electric bell.

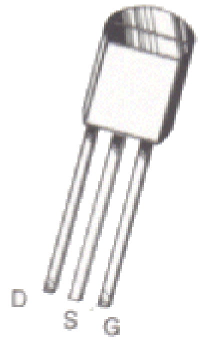
Metronome

This is the simplest metronome circuit. It produces a 'click' similar to that of the traditional mechanical device. The rate is variable from 40 to 220 beats per minute. R1 sets the high rate limit and R2 the low rate limit. Virtually any speaker is suitable. Supply voltage is from 12 to 18v. While an 8 ohm speaker is suitable in this circuit, more volume and higher efficiency can be obtained with a high impedance speaker, such as a 40 ohm unit.



MPF102, 5, 6 Field Effect Transistors

The MPF102-6 series are N-channel Junction-type field effect transistors.
The FET is a three terminal semiconductor device. Input voltage is applied to a GATE terminal and controls the current flowing from SOURCE to DRAIN terminals.
An important feature of the FET is its very high input impedance. Since the FET makes use of a small input voltage to control a large output current, its gain is specified in terms of TRANSCONDUCTANCE. Transconductance (g_{fs}) is equal to the change in drain current (dI_0) divided by the change in gate voltage (dV_G) and the formula is usually written as follows:-
g_{fs} = 100Q(dI_D/dV_G) where:
g_{fs} is the transconductance in micromhos
I_D is the drain current in DC mA
V_G is the gate/source voltage in DC volts.



Definitions of specifications

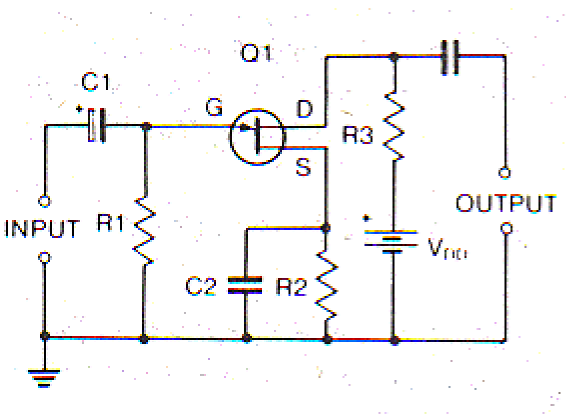
V_{GS} (Gate/Source Voltage)
This is the maximum voltage which may appear between gate and source. I_{DSS} (Drain current at zero gale voltage)
This is the current which will flow in the drain/source circuit when V_{GS} = 0. It is given for specific drain/source voltages.
BV_{GSS} (Gate/Source breakdown voltage)
The voltage at which the gate junction of a JFET will enter avalanche. V_p (Gate/Source pinchoff voltage)
This is the gate-to-source voltage at which the field just closes the conduction channel. This is given for a specified value of V_{DS}. The value of the drain current is specified (usually 1µA).

FET Type	BV_{GSS}	V_P	IDSS	g_{fs}	P_{tot} (mW)
MPF102	25v @ I_G 1µA	0.5-8.0V @ V_{DS} 15v	2-20mA @ V_{us} 15v	2,000-7,500	300mW
MPF105	25v @ I_G 1µA	0.5-8.0V @ V_{DS} 15v	4-16 mA @ V_{us} 15v	2,000-6,000	310mW
MPF106	25v @ I_G 1µA	0.5V-4V @ V_{DS} 15v	4-10mA @ V_{us} 15v	2,500-7,000	310mW

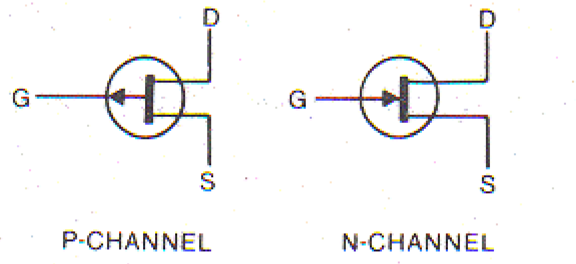
All types are mounted in T092 plastic cases with pin connections as shown above.

Operation and Applications

The basic mode of operation of the FET amplifier is shown below. This is referred to as the common source amplifier. The gate to source circuit is the input and the drain to source circuit is the output.
When a moderate reverse or negative voltage is applied between gate and source, the gate junction becomes 'reverse biased' i.e. the voltage on the gate reduced the current flowing between the source and the drain. At a higher gate-source voltage, the drain-source current is cut to practically zero. This is referred to as the gate-source **pinchoff** voltage and is listed in the specifications as V_P at a drain-source current of either 1 or 10uA. In practical circuits, the DC bias is developed across $R_{2,}$ due to the current being through it. This then puts the source at a positive potential relative to ground. The gate is at ground potential and therefore is at a negative potential relative to the source, R, sets the input impedance of the circuit since the gate of the FET draws virtually no current at all and so is seen by the load as a very high impedance.



***NOTE**
All the circuits and applications in these pages assumes the use of 'N-channel' Junction FETs, i.e. FETs in which the drain-source material is made of N-type silicon. However, these JFETs may be replaced in the circuits with P-channel JFETs if the polarity of the power supply is reversed.

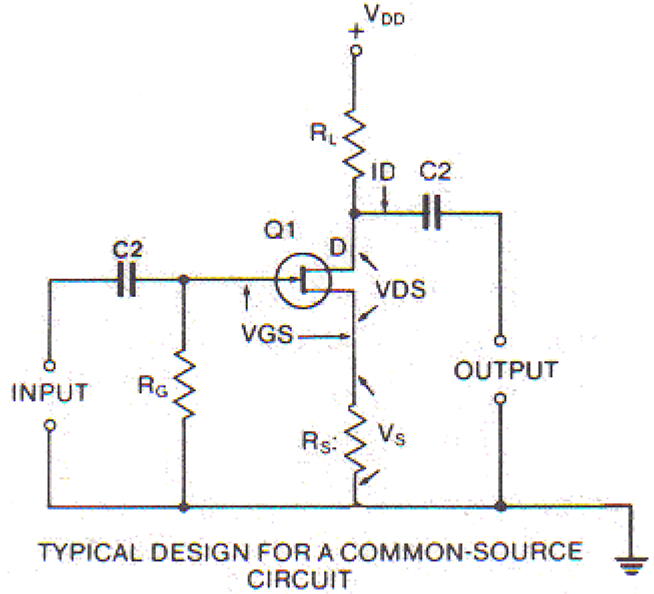


Typical Design for a Common-Source Circuit

When used as an amplifier, the FET is biased to a certain part of its response curve for lowest distortion and maximum available voltage swing. Assume that the FET has the following operating parameters

- V_{Ds} = 8V (where V_{Ds} is the voltage between drain and source)
- I_D = 0.5mA (where I_D is the drain current)

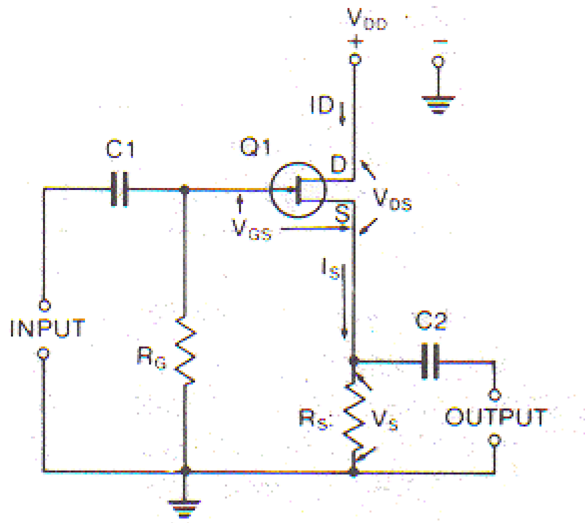
V_{GS} = -2V (where V_{GS} is the gate-drain voltage or bias)
The power supply voltage is 22.5v



TYPICAL DESIGN FOR A COMMON-SOURCE CIRCUIT

FET Applications Source Follower Circuit:

The source follower circuit is suitable where a high input impedance and low output impedance is required, but no voltage gain is needed. The figure below shows a typical source follower stage. Input impedance is set by the gate resistor R_G. Output impedance is very low.

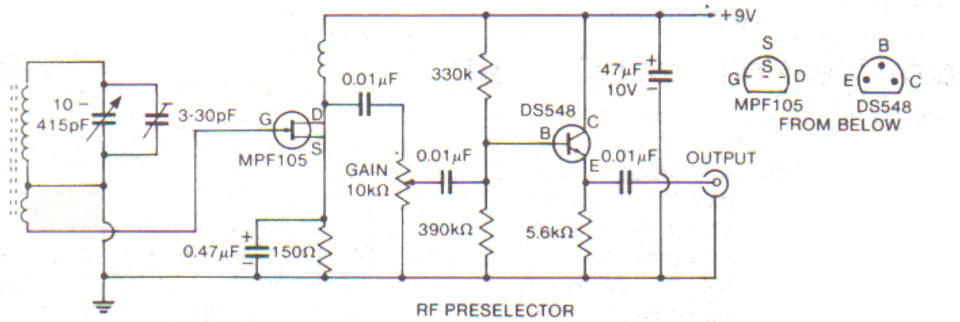


SOURCE FOLLOWER CIRCUIT

RF Preselector

The uses for the FET are not limited to audio applications. The circuit below is for an RF preselector (a tuned amplifier) for the broadcast bands. The FET is a very good device to use in this application, due to its low cross modulation characteristics. Most cheaper receivers use ordinary bipolar transistors to keep costs down. The FET RF amplifier can also take higher signal levels without distortion. The preselector has a Volume Control style gain control between the FET and the emitter follower output stage. This means that only the FET has to handle high signal levels.

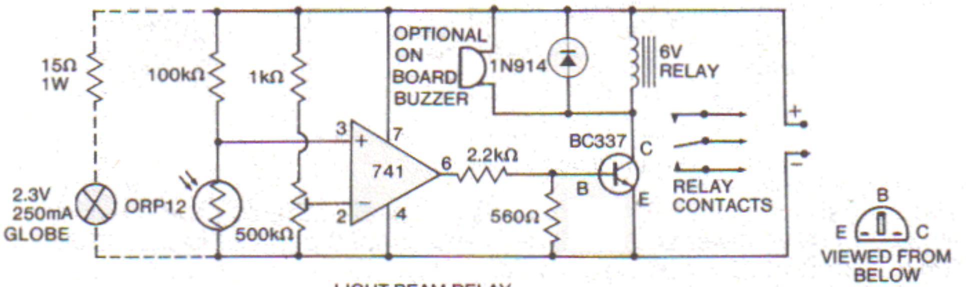
The tuning capacitor does not have to be exactly the same value as shown in the circuit, any capacitor covering a similar range is suitable. The aerial coil is wound on a 200mm length of ferrite rod. The main winding consists of 42 turns of 22B&S enamelled wire. The second winding consists of a further 6 turns. The preselector gives a marked improvement on the reception of weak signals and aids in the attenuation of adjacent channel interference and noise.



RF PRESELECTOR

LDR Applications Light Beam Relay

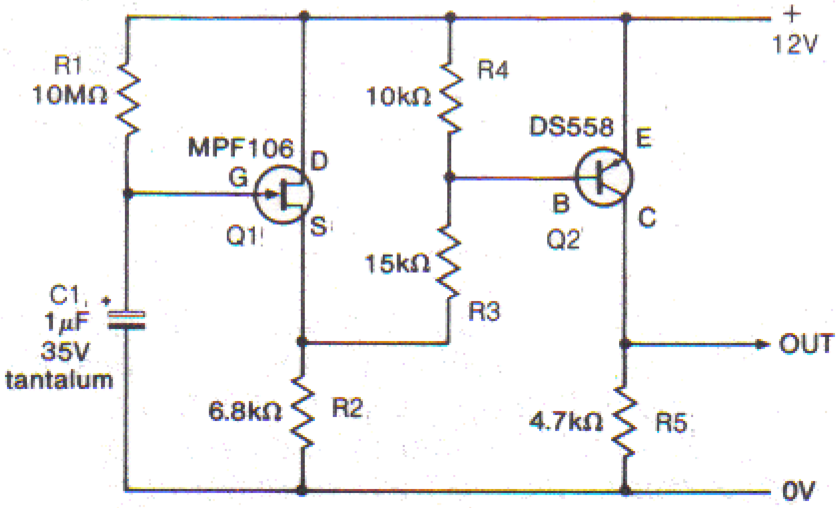
In this circuit the LDR is held at a low resistance by light from a small globe. The circuit is actuated when the beam is broken. The resistance of the LDR then goes high. The circuit is set up so that with the light shining on the LDR the input voltages at the two input terminals of the 741 op amp hold its output 'low'. When the LDR goes to high resistance the op amp's output goes 'high'. This turns the transistor 'on' and pulls in the relay.



LIGHT BEAM RELAY

Simple timer

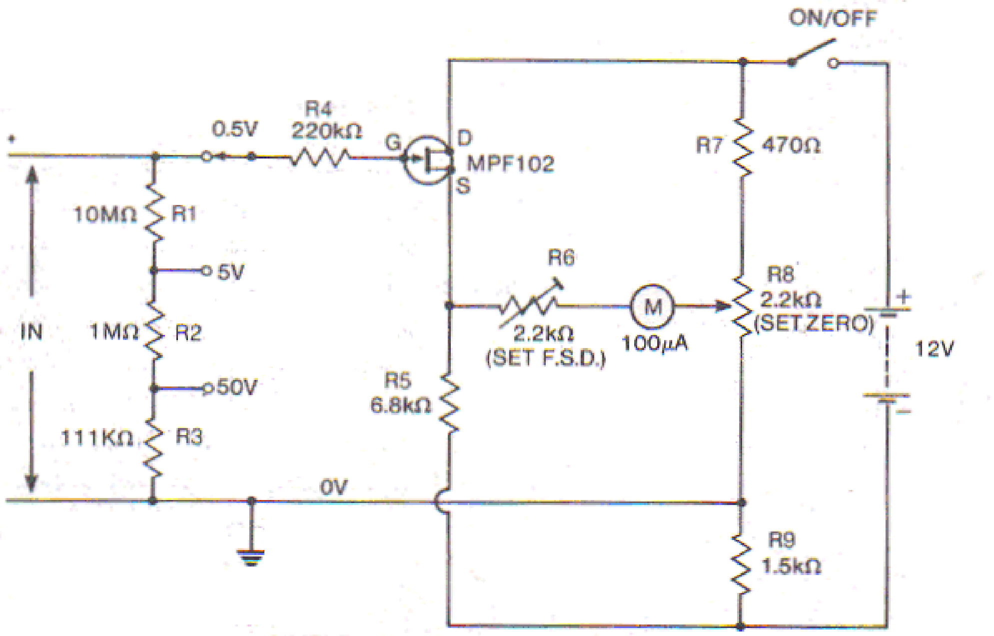
The very high impedance of the FET makes it suitable for a wide variety of timer circuits. The circuit below gives one such example. With C_1 given a value of 1μF, it will give timing periods of 40 sec, and with a value of 100μF it gives a period of 35 minutes. The FET is wired as a source follower and has its gate taken to the junction of a time constant network R_1-C_1 When the supply is first connected, C_1 is discharged, so Q_1 gate is at ground potential, and the source is a volt or two higher. The base of Q_1 is connected to the source of Q_1 via R_3, so Q_2 is turned on and 12v is across R_5, When the supply is connected, C_1 starts to charge via R_1, so the voltages on the gate of Q_1 (and on the source) rise exponentially towards the 12v supply. When the voltage reaches approximately 10.5v the bias on Q_1 falls to zero and Q_2 switches off, the voltage across R_5 falls to zero.



SIMPLE TIMER

FET Voltmeter

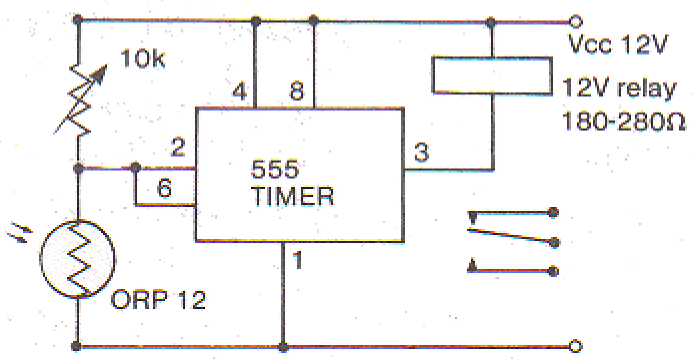
The very high input impedance of the FET makes it the ideal basis of a voltmeter. The circuit below has a basic sensitivity of 22M ohms per volt. Maximum full scale sensitivity is 0.5V, and input sensitivity is a constant 11.1 M ohms on all ranges. R_7,R_8 R_9 form a potential divider across the 12v supply. R_8 is adjusted for a zero meter deflection. Any potential across the gate circuit of Q1 causes the circuit to 'unbalance'. To avoid drift, the power supply should be stabilized if possible.



SIMPLE 3 RANGE VOLTMETER

555 Light Switch

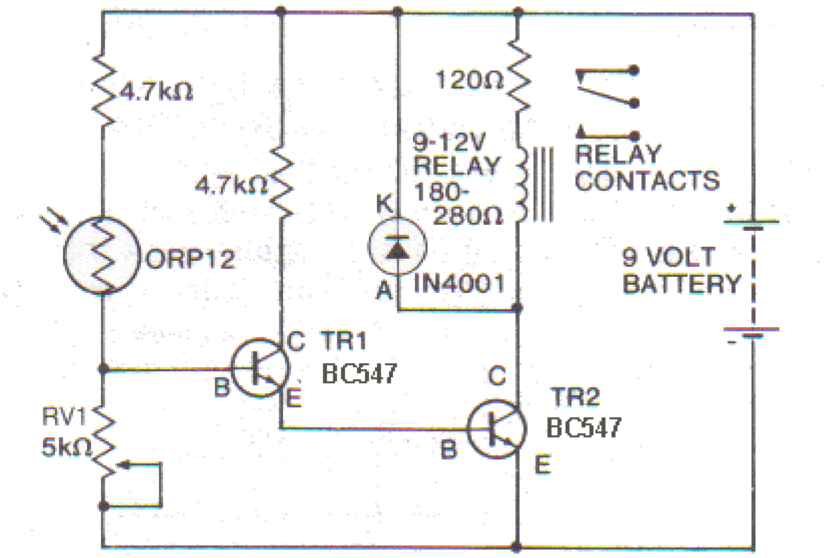
The use of the 555 timer 1C with an LDR provides a high performance light switch.
An LDR is a Light Dependent Resistor and is a very low cost way of detecting light.
The 555 is used with its trigger and thresholds tied together to provide a Schmitt trigger with a very low input current but which can drive a relay taking up to 200mA of current. The trigger is activated when the light level on the LDR falls below a predetermined level. The relay energizes when the voltage on pins 2 and 6 is greater than $^2/_3V_{cc}$. It de-energizes when the voltage falls below $^1/_3V_{CC}$. This gives a hysteresis of $^1/_3V_{CC}$.



The 555 can supply current up to 200mA, so the relay type is not critical. Any with a coil resistance from 100-280 ohms would be suitable.

Light Sensitive Switch

This circuit makes use of the wide change of resistance of the LDR. Between positive and negative supply there is a voltage divider. The bottom section is a variable resistor RV1. The top half is formed by the LDR and a 4.7K ohm resistor in series. In low light conditions when the resistance of the LDR is very high, the bias to the Darlington pair formed by TR_1 and TR_2 is very low, and they do not conduct. When the light level rises, the resistance of the LDR falls. This turns the transistors 'on' and pulls in the relay.



LIGHT SENSITIVE SWITCH

The LDR should be an ORP12 or similar. The relay should have a pull in voltage of 9V or lower and a coil resistance of 280 ohms or higher.

Photo Electric Relay

This circuit is basically a bistable multivibrator. When the light level is low and the resistance of the ORP12 is high, transistor Q_1 conducts and Q_2 is off. As the level of illumination increases the resistance drops until Q_1 cuts off and Q_2 turns on, energizing the relay coil.

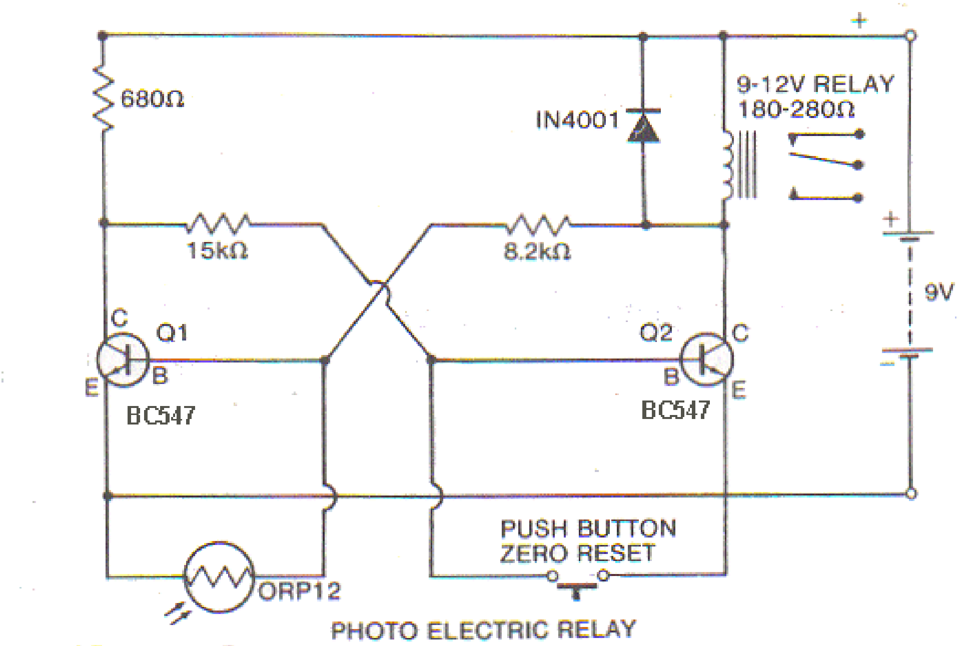


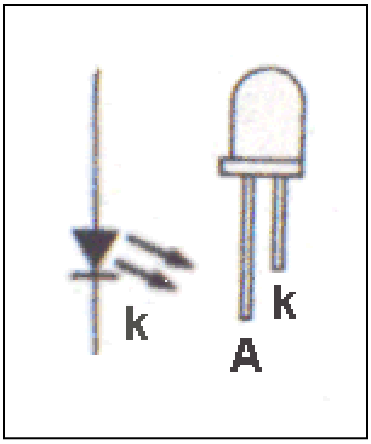
PHOTO ELECTRIC RELAY

The relay should have a coil resistance of 180 ohms or higher and a pull in voltage of 9V or lower

LEDs

Features

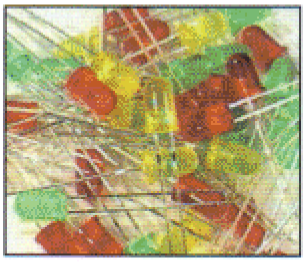
- Low power consumption
- IC compatible
- Long life



Absolute Maximum Ratings

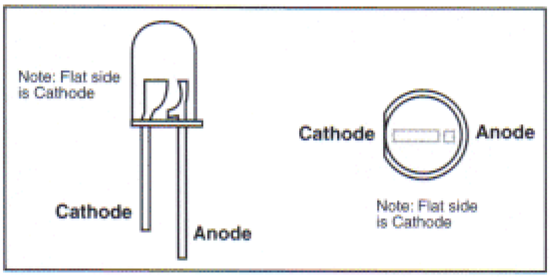
	Red	Green	Yellow	Amber	Orange
Reverse Voltage	5v	5v	5v	5v	5v
Av forward Current	20mA	30mA	30mA	30mA	30mA
Peak Forward Current	200mA	200mA	200mA	200mA	200mA
Power Dissipation	100mW	100mW	100mW	100mW	100mW

Light Emitting Diode Data



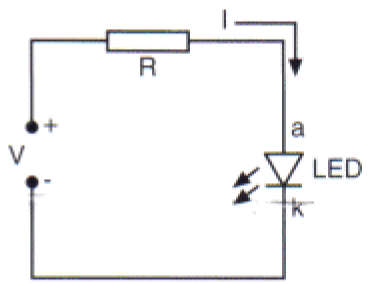
Light Emitting Diodes, or LEDs as they are known are a special type of diode which emits light when correctly powered. Typical voltage and current for every LED in the Altronics range can be found in the components section.

The LED's legs are called anode and cathode. The anode is the leg that needs to be connected to the positive of the power source. Normally a LED has different lead lengths to identify which is the positive lead. However if the leads have been trimmed, the cathode is denoted by a flat face on round LEDs or the larger internal part of the LED.



Ohms Law dictates the following:

$$R = \frac{(V_S - V_{LED})}{I_{LED}}$$



Where: V_S = Voltage source
V_{LED} = Volt drop of LED
I_{LED} = Current draw of LED

If I_{LED}= 20 mA @2.0V
If V_S = 3 Volts, R_1 = 50Ω
If V_S = 6 Volts, R_1 = 200Ω
If V_S = 9 Volts, R_1 = 350Ω
If V_S = 12 Volts, R_1 = 500Ω

These values can be substituted for the closest 5% resistor values.

For 3 Volts	R	=	56 Ohms
6 Volts	R	=	220 Ohms
9 Volts	R	=	390 Ohms
12 Volts	R	=	560 Ohms

LED Basics

Specifications

Forward Voltage (I_F = 20mA)

Red	1.7v Typ.	2.0v Max
Green	2.2v Typ.	2.8v Max
Yellow	2.1v Typ.	2.8v Max
Amber	2.1v Typ.	2.8v Max
Orange	2.0v Typ.	2.8v Max

Peak Emission Wavelength

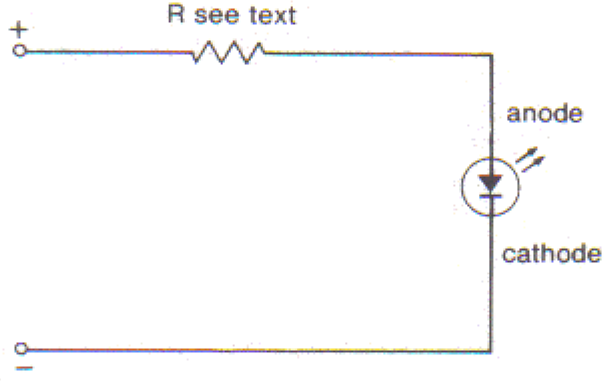
Red	697nm
Green	565nm
Yellow	585nm
Amber	600nm
Orange	635nm

Note: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE eye response curve.

LEDs are used in the 'forward biased' mode. i.e. positive on the anode and negative on the cathode. This voltage drop is stated in the specifications (eg 1.7V for a red LED), If the LED is used on a higher voltage than this, a current limiting resistor must be used.

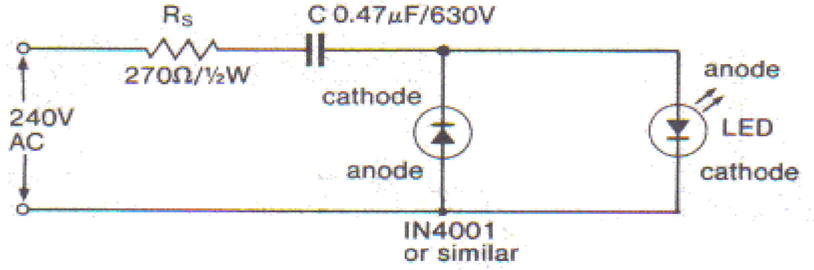
The following formula can be used:-

R = (E -1.7) x 1000/I
R is the resistance in ohms. E is the DC supply voltage. I is the LED current in milliamps.
A common LED current is 20mA.
Some calculated values are:-
For 6v use 220 ohm.
For 9v use 390 ohm.
For 12v use 560 ohm.
For 24v use 1.2k ohm.
If a LED is reverse biased, it will break down, in a similar way to a zener diode. This occurs at 3-5V. It usually damages the diode if a high current flows.



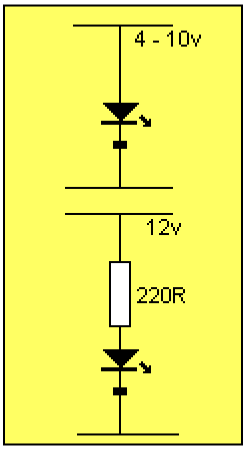
Operating LEDs from the mains

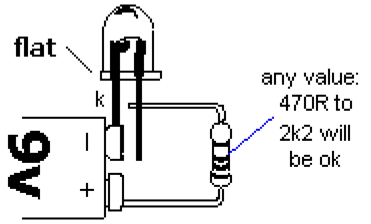
This circuit uses a capacitor as a voltage dropping element. A 1N4148 diode is placed across the LED for rectification. As the voltage across the LED is negligible compared with the supply, capacitor current is almost exactly equal to mains voltage divided by the capacitor reactance. At 50Hz, a 0.47µF will result in a LED current of about 16mA. Resistor R_s limits current on transients. A value of 270 ohms is adequate.



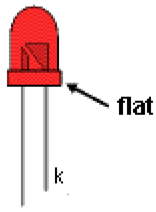
The Flashing LED

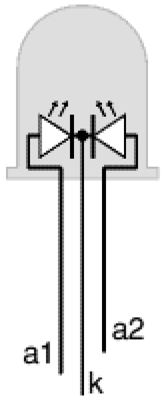
The Flashing LED has a chip inside the device to produce the flash-rate. Simply connect the LED to a supply voltage (4v to 10v) and the LED will flash at a rate of approx 2Hz. No external resistor is needed up to 10v. For voltages higher than 10v, the resistor should be 100 ohms for each volt above 10v.
This is the only “LED” that does not need a resistor when connected to a supply as it has an internal resistor. All other LEDs MUST have a resistor in series to limit the current and prevent damage.





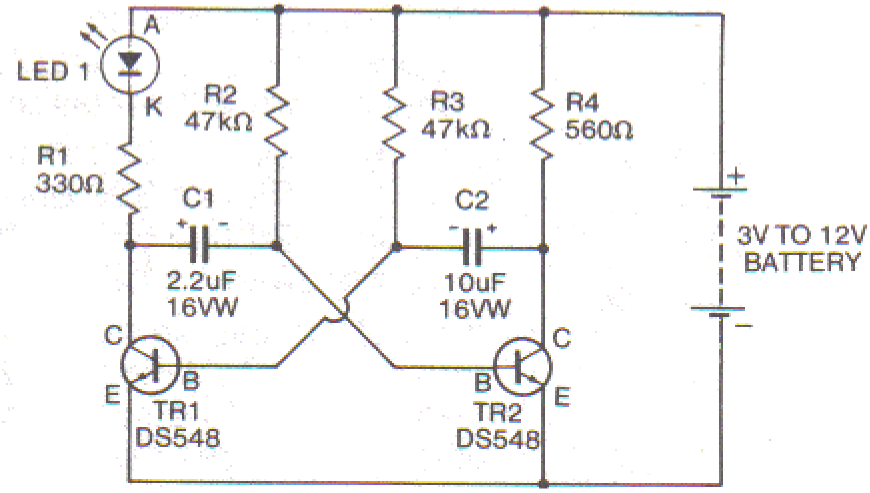
Testing a LED. The LED will illuminate when it is around the way shown in the diagram. The flat on the side of the LED indicates the cathode lead.





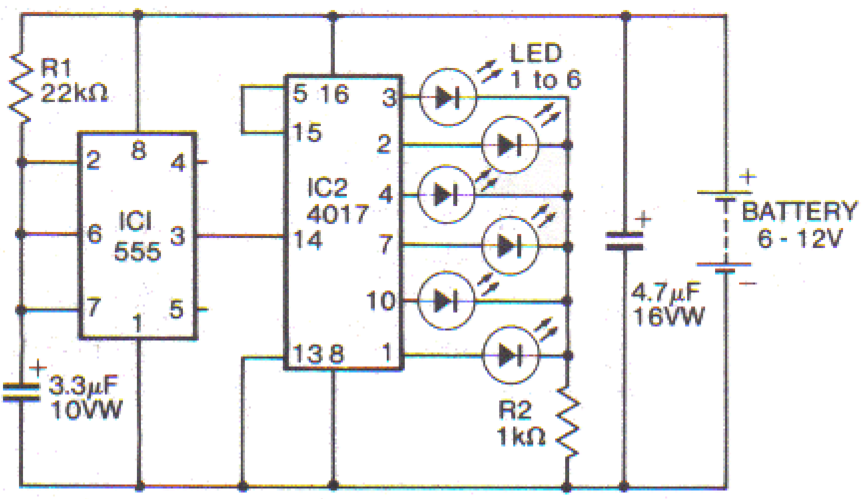
LED Flasher

This circuit for a LED flasher is very simple and cheap to make and will work on any voltage between 3v and 12v. As the voltage is raised the value of R1 must be increased - The speed can be changed by altering the value of C_1 and C_2 and/or R_2 or R_3. Raising the value of C_1 and C_2 slows the rate down. Raising the value of R_2 and R_3 also slows it down.



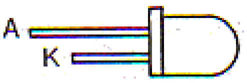
LED Chaser

This circuit acts as a LED chaser. The 4017 is driven by a 555 working as a free-running multivibrator. The speed can be changed by altering C_1 or R_1.



CQY89 Light Emitting Diode - Infrared LED

The CQY89 is an infrared LED, similar in performance to conventional LEDs, but emitting light in the infrared region. This is visible to the human eye. Unlike conventional LEDs, infrared LEDs are usually pulsed rather than fed with continuous DC. They find wide use in alarms and in remote control equipment.



Specifications

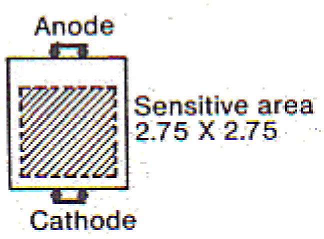
Maximum Forward Current 130mA
Maximum Reverse Voltage 5V
Maximum Power Dissipation 215mW
Maximum Forward Current 130mA
Beamwidth between half intensity directions (I_F = 100mA] 40° typ.
Wavelength at peak emission (l_r = 100mA) (λ_{pk}) 930nm typ.

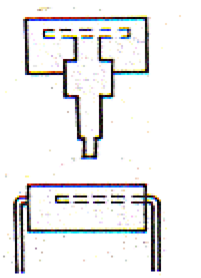
BPW34 photosensitive diode

This device is mainly used in combination with a light source for go/no go detection as in card readers and industrial safety devices.

Specifications

V_R Forward voltage 32V
Total power dissipation 150mW
Spectral sensitivity (V_R =5V) 70nA/lx
Dark Reverse Current (V_R=10; E_e=0) 2nA
Light Reverse Current
(V_R = 5; E_e= 1mW/cm^2;λ = 930nm) 10µA

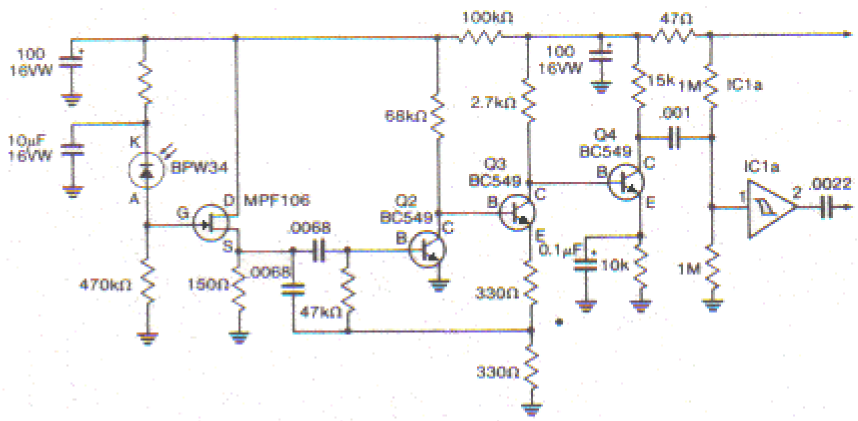




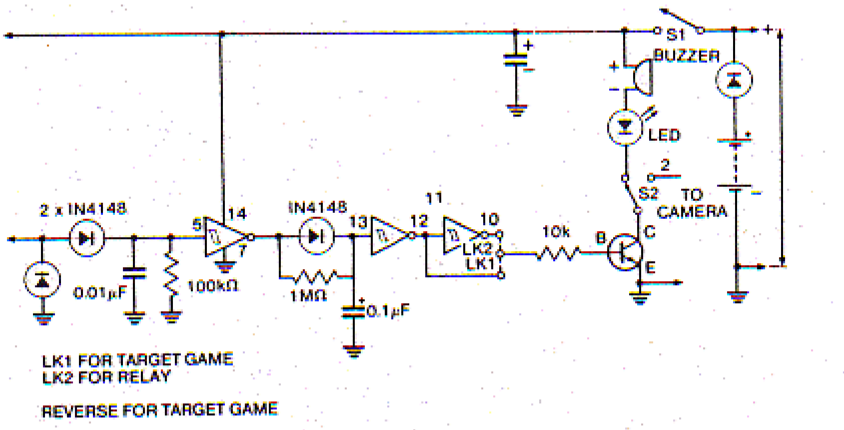
BPW34/CQY89 Infrared light-beam relay

Receiver

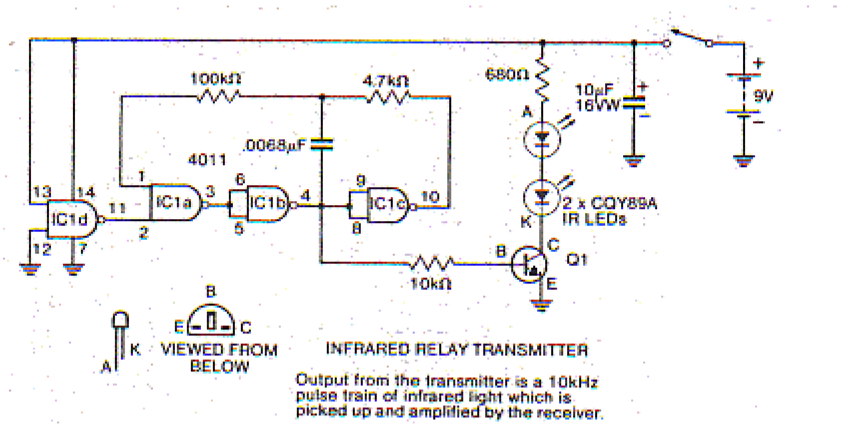
The light is picked up by the photodiode a BPW34. It is wired so that a current is generated that is proportional to the light falling on it. The FET acts as a source follower and impedance matches to the next stage. The amplifier after this acts as a bandpass filter. Its output is coupled to a CMOS Schmitt trigger, followed by a rectifying circuit and a pulse stretcher. This drives a transistor and a buzzer and LED.



INFRARED LIGHT BEAM RELAY

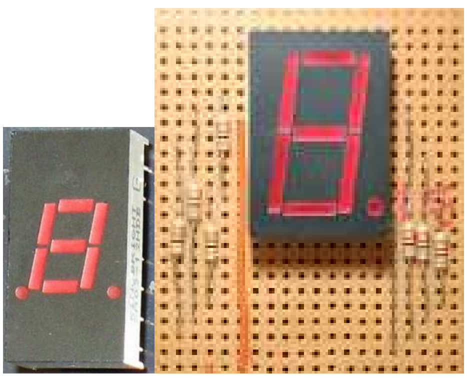


Transmitter
A CMOS oscillator drives an output stage consisting of a BC547 transistor and two CQY89 infrared LEDs. Current drive is limited by the 680 ohm resistor. If greater range is required, this resistor may be reduced to a minimum of 150 ohms with a consequent increase in current consumption.



7 Segment LED Displays

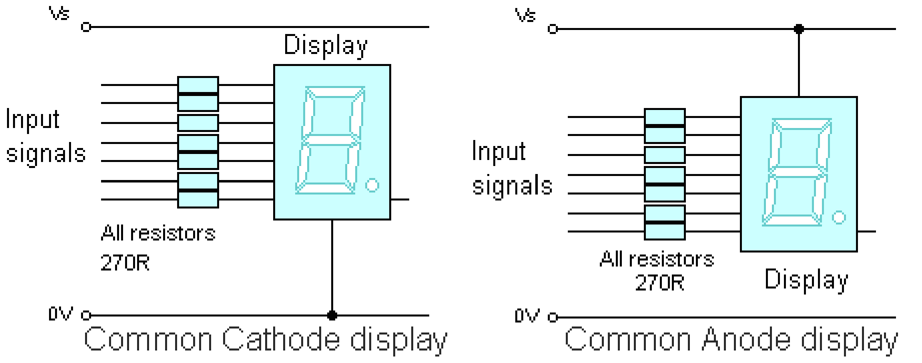
The 7 segment display is found in many displays such as microwaves, lifts, ovens etc. It consists of 7 LEDs that have been combined into one case to make a convenient device for displaying numbers and some letters. There are basically two different size displays. 0.3” and 0.5”. The two sizes are shown below:

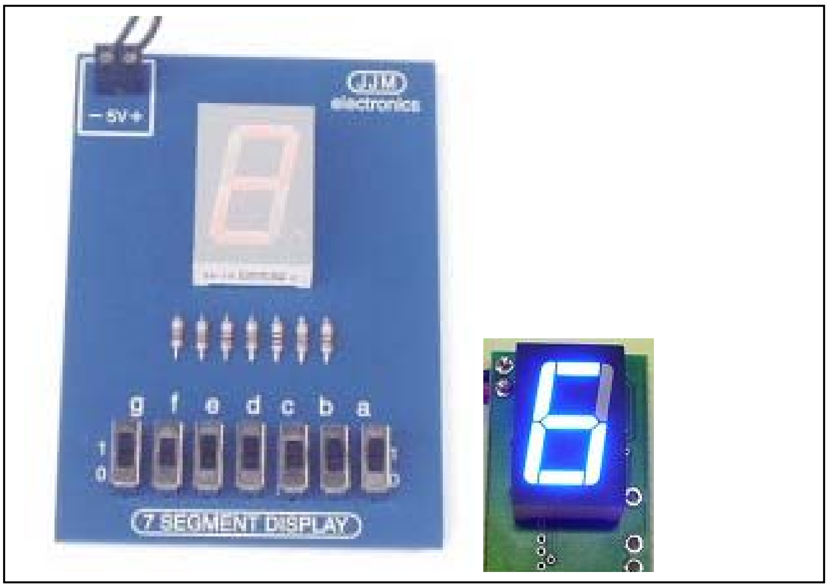


0.3” and 0.5” 7-segment displays

Displays come is a range of colours and brightness levels.
Most come in super-bright and these are preferred so the display can be seen during the day. They are not much more expensive but give a much better illumination.
All displays also come in COMMON CATHODE and COMMON ANODE.
The COMMON CATHODE display has all the cathodes of the LEDs tied together and connects to the pin that goes to the 0v rail. This is the most common type of display.

The Common Cathode and Common Anode displays are wired as shown below:

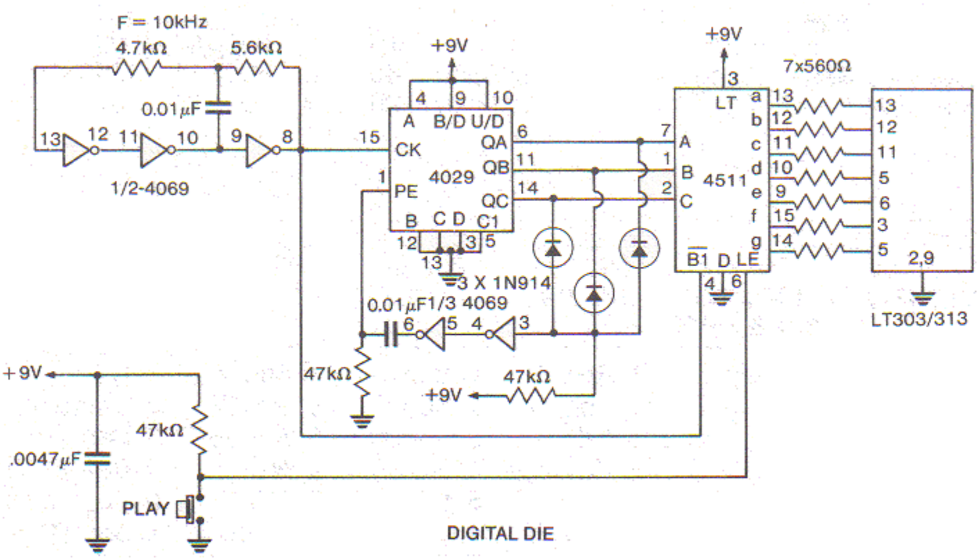




The project above from **JJM** turns on each segment of the display to show how each letter and number is produced. The second photo is a white 7-segment display.

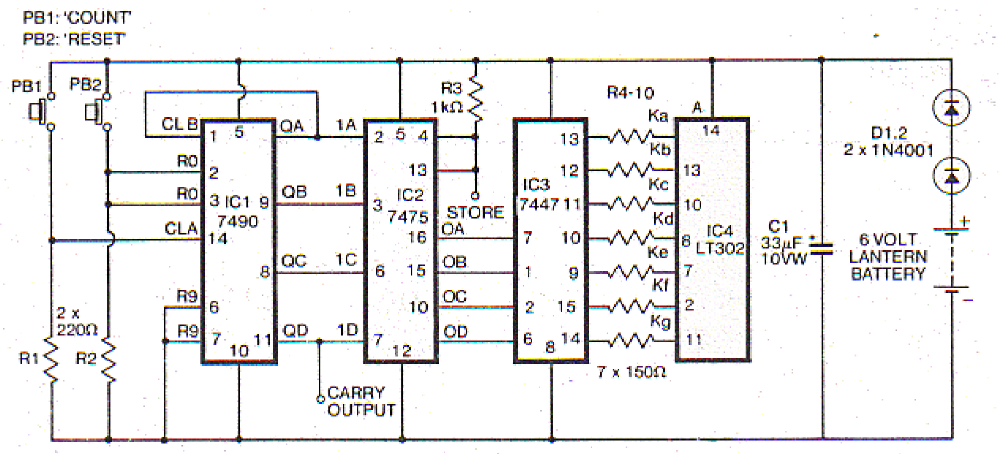
Electronic Die

This circuit consists of three sections: an oscillator, a counter, and the display. The oscillator uses three sections of a 4069 hex inverter. The 4029 is a four bit counter with the capacity to count from zero to 15. The 4511 driver/decoder takes binary output and decodes it to drive a seven segment display. The current to the 7-segmenl display is limited by seven 560 ohm resistors. The display is a common cathode type, and any 7-segment display can be used.

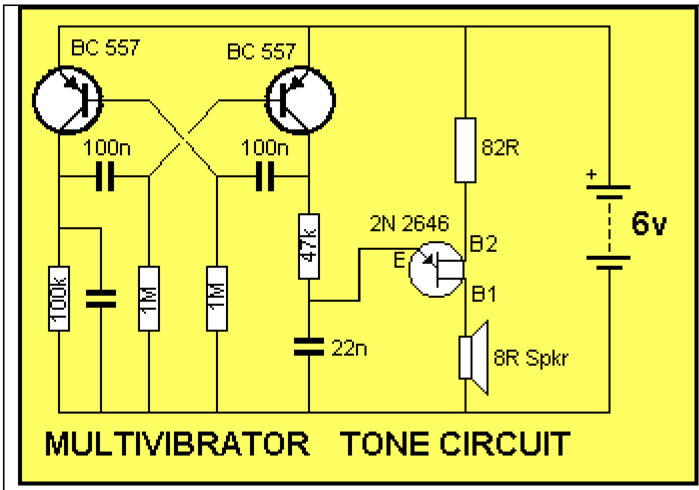


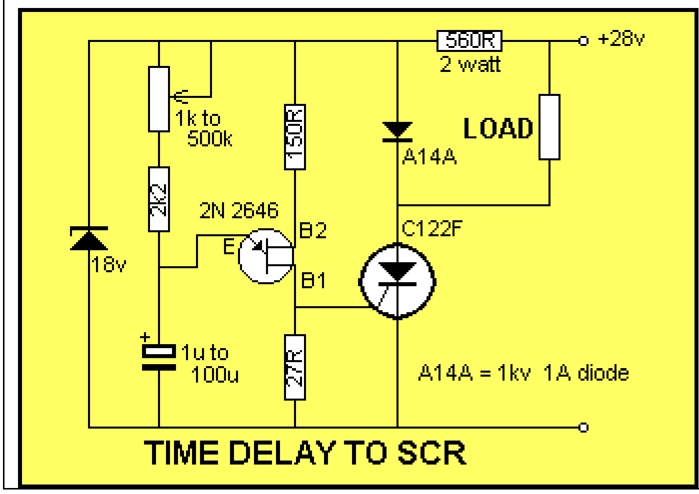
Counter

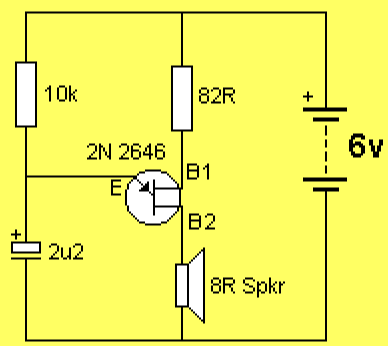
This circuit uses a 7-segment display as the output of a basic counter circuit. The 7490 counts decimal pulses and converts them to a BCD code. Its output is fed to a 7475 latch. This stores the outputs from the decade counter. The four binary outputs are taken from the 7475 to a 7447 LCD to the 7 segment LED decoder, which drives the display.



THE UNIJUNCTION TRANSISTOR

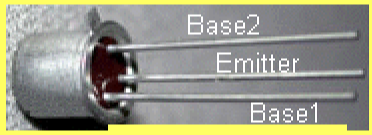


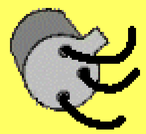




UNIJUNCTION TRANSISTOR OSCILLATOR

The output of the oscillator is a sawtooth The higher the supply voltage, the lower the output frequency.

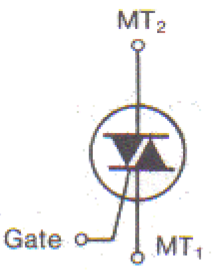


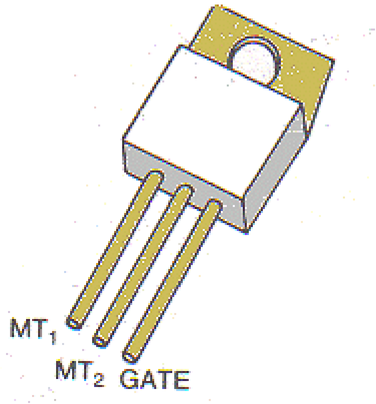


2N 2646

SC151D TRIAC

The SC151 D is a medium power plastic package TRIAC designed for economical mains power and lighting control. Unlike SCRs, the SCI 51 D is a bidirectional thyristor - when triggered, it conducts in both directions and can be triggered by a positive or negative gate signal. TRIAC (Triode AC Semiconductor). The diagram below shows the V/I characteristics of the Triac. A gate current of the specified level of either polarity will trigger the triac into conduction in either quadrant, provided the applied voltage is less than V_{B0}. Triggering may be from DC, rectified AC or pulse sources such as unijunctions, neon lamps or breakdown devices such as the ST4.





Specifications

Voltage Rating	400V
Current Rating	15A RMS
I_{TSM} Maximum peak one cycle non rep. surge current	110A
I_{DRM} Blocking Current at 25°C	0.1mA max
dv/dt Off State, T_c = 100°C, Rated V_{DRM}, gate O/C	250V/μS (typ.)

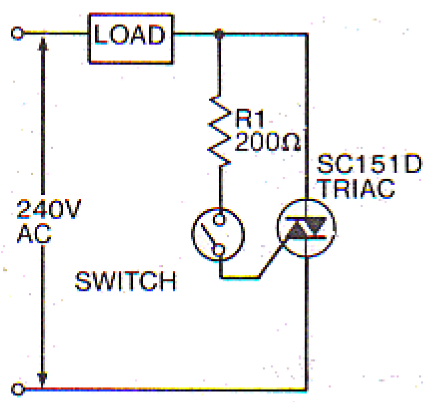
FIRING

I_{GT} Max DC Gate Trigger current V_D=12v, 25°C	50mA
V_{GT} Max Gate Trigger voltage V_D= 12v 25°C	2.5V

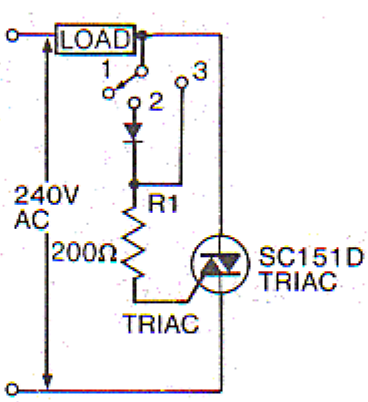
Triac as a switch

This gives improved performance over a conventional switch, as there can be no arcing or contact bounce. This circuit shows a simple three position power control. In position one there is no gate connection, so power is off. In position two there is gate current during one half cycle only and load power is half wave. In position three the gate is triggered on both half cycles and the power is full on. For a simple on-off switch, just delete the diode.

Because the contacts only carry current for the few microseconds needed to trigger the triac, the actual switch can be almost any small device: reed relays, thermostats, pressure switches or program/timer switches.



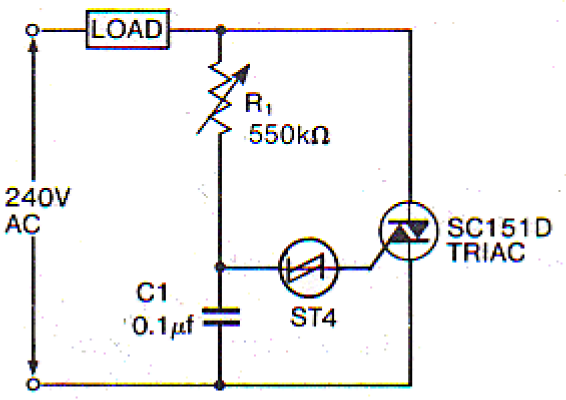
BASIC STATIC SWITCH



3 POSITION STATIC SWITCH

Lamp dimmer/Heater controller

R1 and C1 are a phase shift network - they produce a variable delay in the waveform applied to the ST4 and hence the triac. When the voltage across C1 reaches the breakdown voltage for the ST4, C1 partially discharges into the triac gate through the ST4. This pulse triggers the triac into conduction for the remainder of the half cycle.



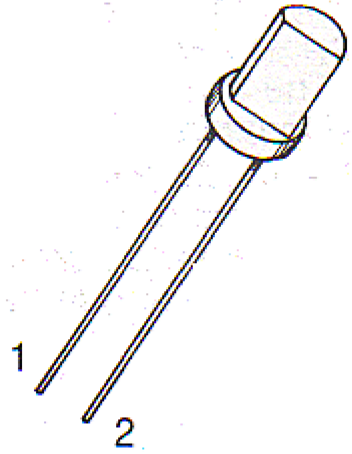
This easy-to-build controller is ideal for dimming lights, and controlling the output of electric heating type appliances. The light or heater element etc is placed where the 'LOAD' is marked on the circuit.

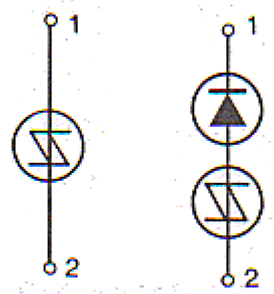
ST4 Asymmetrical AC Trigger Switch

The ST4 is an integrated triac trigger circuit that provides wide range hysteresis-free control of voltage.
It behaves like a zener diode in series with a silicon bilateral switch (a symmetrical device).
The zener provides asymmetry since the switching voltage is increased in one direction by the zener breakdown voltage.

Switching voltage:
V_{S1} 14v-18v
V_{S2} 7-9v
Switching current
I_{S1} I_{S2} 80µA

On-state voltages
V_{F1} (I = 100mA) 7-10v
V_{F2} (I = 100mA) 1.6v max
Peak pulse voltage
V_0 3.5v min



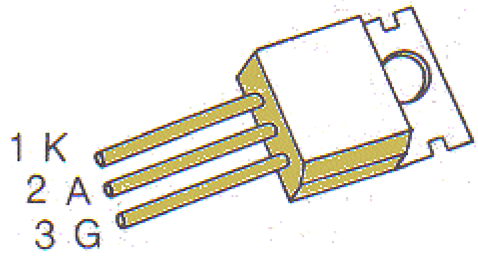


SYMBOL OF ASYMMETRICAL AC TRIGGER SWITCH (ST4) AND EQUIVALENT CIRCUIT

C122D/C122E Silicon Control Rectifier

The C122Dand 122E are medium power plastic package SCRs designed chiefly for mains power and motor control. The SCR is a unidirectional device, (current flows through it in one direction, from anode to cathode).

The SCR is a three terminal semiconductor device. The three terminals are the anode (A), cathode (K). and the gate (G). With no voltage applied to the gate terminal, if a voltage is applied to the SCR anode and cathode terminals, (anode positive with respect to cathode) current flow is prohibited. If the supply is reversed the flow is likewise prohibited. Thus with no signal applied, the SCR appears as an open circuit as long as its diode junctions do not break down. The SCR is brought into conduction by applying a current into the gate terminal. This will cause it to conduct in the forward direction (i.e. with the anode positive and the cathode negative). The gate voltages required vary from approximately 1.5- 6.0v. Once the SCR is turned on the gate no longer controls the circuit and the SCR only drops out of conduction when the anode-cathode voltage falls to near zero. At this instant, the current through the device falls to zero.

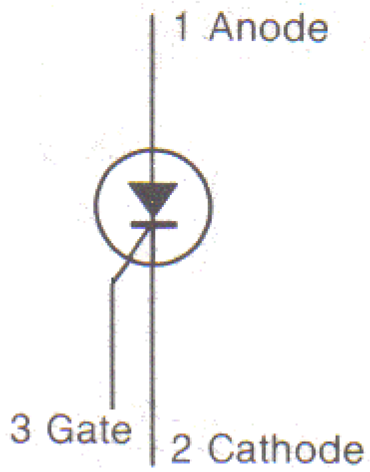


Specifications

C122E

V_{DRM} (Repetitive off state voltage. Max between anode and cathode)	500V
I_T (RMS Current through SCR)	8 Amps
I_{GT} (Peak Positive gate current) (T_c = 25˚C)	25mA
V_{GT} (Peak Positive gate voltage) (T_c = 25˚C)	1.5V
P_G (AV) (Max Gate power)	0.5W
I_H Holding Current (Current below which the SCR will drop out of conduction) (T_c = 25˚C)	30mA
dv/dt Rate of change of on-state voltage (Max. rate of change of anode-cathode voltage which will not turn SCR on)	50V/µsec(typ.)

The C122D differs only in that its V_{DRM} is only 400v as against 500v for the C122E.

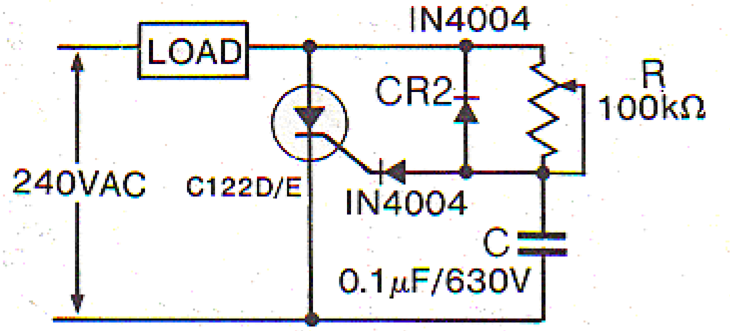


The SCRs listed above are medium power SCRs (Silicon Controlled Rectifiers) designed primarily for economical mains power and motor control. They are three terminal devices (see above). The electrodes are anode, cathode and control gate. They are unidirectional devices i.e when triggered 'on' they only conduct in one direction. The SCR is a 'regenerative' device. It is triggered 'on' by injecting a signal into the gate. As noted earlier, once the gate has triggered the SCR 'on' it no longer controls the gate. The only way to cause the SCR to stop conducting from cathode to anode is to drop the anode cathode voltage to a level where the current flowing from anode to cathode is below the 'holding level'. This is indicated in the figure above. In practice, this is not a problem, since SCRs are normally used to control fluctuating voltages such as the AC mains. The 'drop out' of the SCR occurs as the mains voltage goes through zero.

Applications

SCRs are current rather than voltage triggered devices. This means that they must be fed from a relatively low impedance source i.e. one in which the voltage won't drop down under load from the gate. In a way analogous to a relay or a solenoid, the SCR requires certain minimum anode current if it is to remain in the 'closed' or conducting state. If the anode current drops below the minimum level, the SCR reverts to the forward blocking or 'open' state. The following circuit shows a basic R-C-Diode trigger circuit giving full half wave control. On positive half cycles the capacitor C will charge to the trigger point, at a speed determined by the time constant of R and C. On the negative half cycle, the capacitor is reset by CR_2, resetting it for tire next charging cycle, Thus the triggering current is supplied by the line voltage.

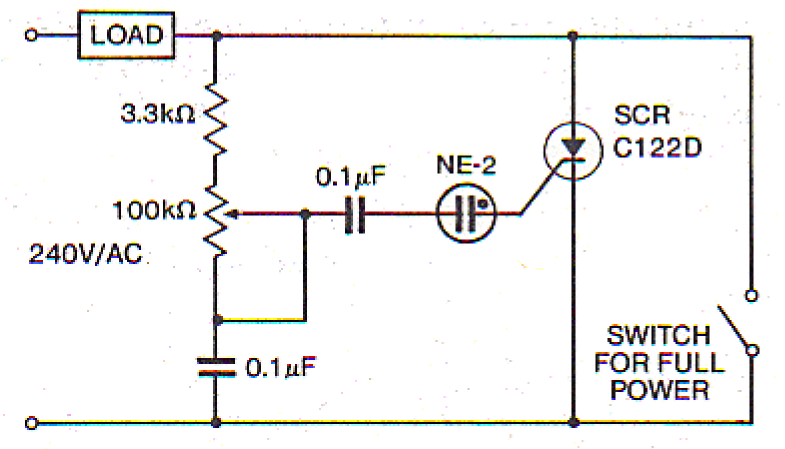
C122D, C122E, C106D SCRs **Phase Control Circuit**



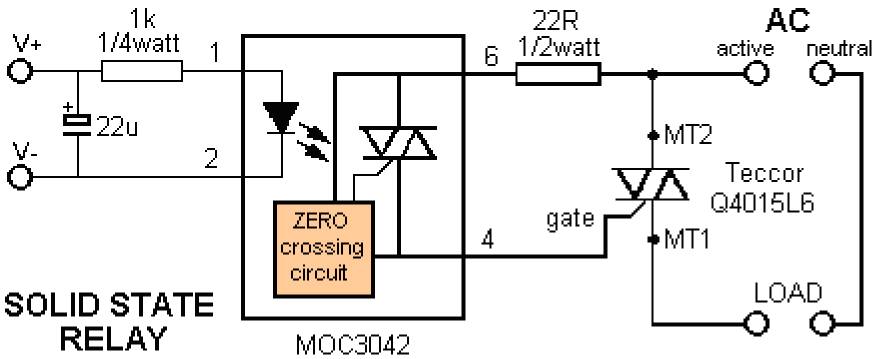
Improved phase control circuit

The following diagram shows a circuit using a neon lamp as a breakdown device. This gives smoother control and improved performance. The neon triggers when the voltage across the two 0.1µ capacitors reaches the breakdown voltage of the lamp (60-90V). Control extends from 95% to full off.

The neon lamp phase controlled circuit shown below combines the low cost of the simple RC circuit shown before but gives improved performance. The circuit below gives half wave control from 95% on to full off. Full power can be easily obtained by putting a switch across the SCR. The circuit uses a neon. This gives the following improvements:
A higher impedance circuit can be used for control.
As a result, the control element (which is a 100k pot in the circuit below) can be replaced by a high impedance device such as a thermistor or light dependent resistor, for heating or light control applications.

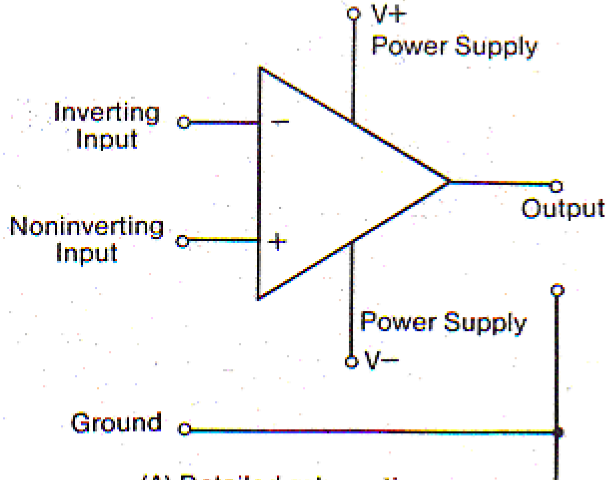


HALF WAVE/TWO TERMINAL

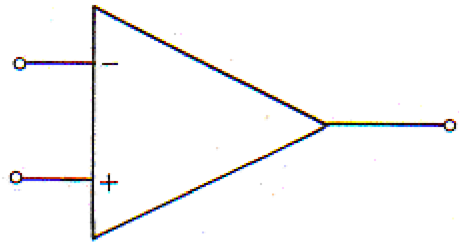


OP-AMP Basics

The op-amp is a very high gain DC amplifier. This is quoted in specifications as typically in the range of 20,000 to 100,000 times. The symbol for the op-amp is shown below. As can be seen, there are two inputs, the inverting and the non-inverting. If a signal is applied to the -input (inverting) with the + input (non-inverting) grounded, the polarity of the output signal will be opposite that of the input. If the signal is applied to the + input with the - input grounded, the polarity of the output signal will be the same as the input signal. For an AC signal, this means that when it is applied to the - input, the output signal will be 180° out of phase with the input. If the same signal is applied to both the + and - inputs, the two signals will cancel each other out. The op-amp responds to the difference between its two inputs - hence the name differential amplifier. The ability of an op-amp to cancel two equal signals at its pins is referred to as its common-mode rejection.

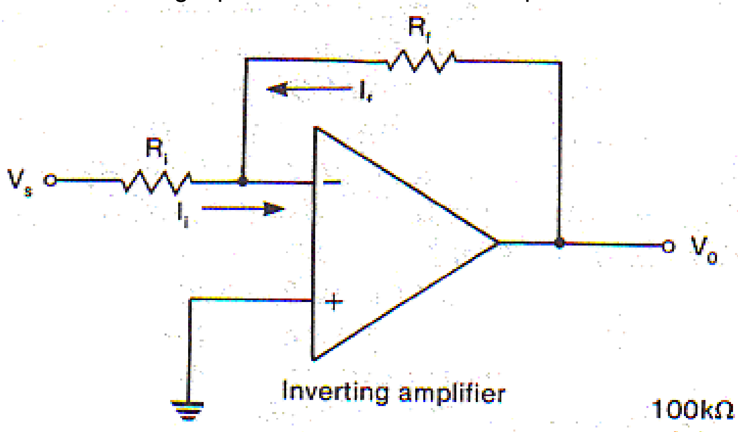


(A) Detailed schematic

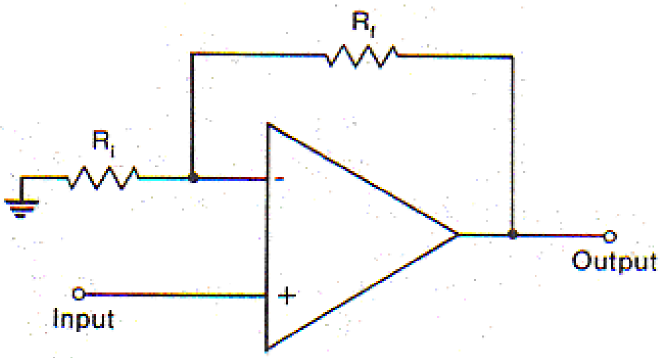


(B) Simplified schematic

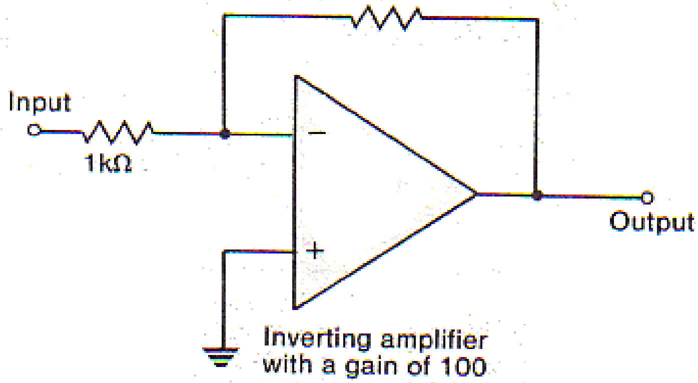
The most common op-amp circuit is shown below and uses two external components;
1) an input component, R_1
2) a feedback component, R_F.
When the feedback component is between the op-amp output and the negative input the op-amp is said to have negative feedback. When the feedback component is between the op-amp output and the positive input, the circuit is said to have positive feedback.
With no feedback applied, the gain is set by the op-amp itself and is very high (at very low frequencies). This is referred to as the open loop gain. When negative feedback is applied, the gain is specified by the feedback components, and is referred to as the 'closed loop gain'.
Gain = R_f / R_i
Thus to produce an amplifier with a gain of 100, we can use an input resistor of 1k and a feedback resistor of 100k. This is shown below with the op-amp connected as an inverting amplifier. To produce a non-inverting amplifier, the signal is applied to the non-inverting input and the feedback components are left on the non-inverting side. This is shown following.



Inverting amplifier



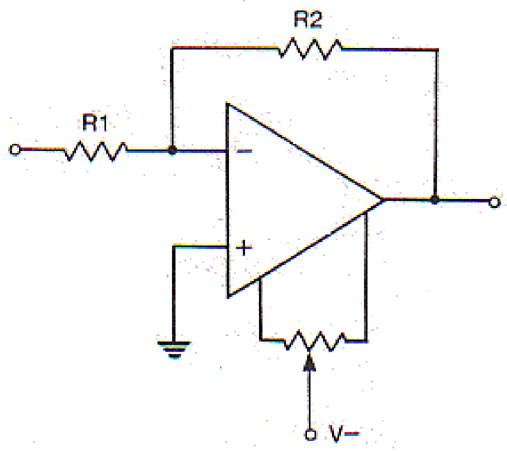
Non-inverting amplifier



Inverting amplifier with a gain of 100

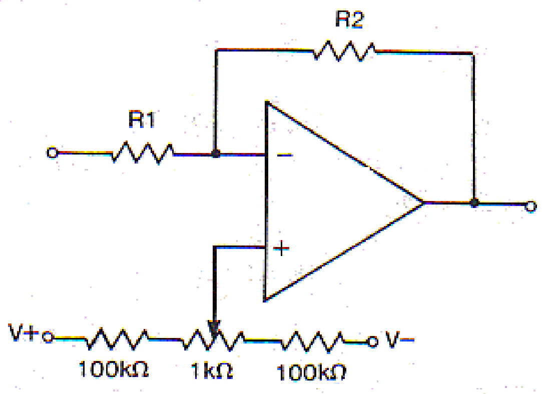
Output Offset

The steady state output of an op-amp with negative feedback is zero when the input is zero. The actual DC output (in a real op-amp) is usually not quite zero, and this small unwanted signal is usually referred to as the output offset voltage. Most op-amps have means of nulling this out. Fig A shows the most common method, where the op-amp has special nulling pins. If these are not available, the method in Fig B can be used.



Output offset null circuit for op amps with internal nulling provisions.

Fig A



Output offset null control for op amps.

Fig B

Frequency Compensation

Circuits using op-amps must be designed so that the open loop gain of the op-amp itself is greater than the closed loop gain of the circuit for all frequencies of operation. The gain drops as the frequency increases. This is mainly due to the large amounts of internal 'compensation' used to make sure that they do not oscillate. Frequency compensation is the shaping of the frequency responses of the op-amp so that it does not oscillate due to internal phase shift. This phase shift acts as a time delay. When this delay is great enough so that the input signal is delayed 360° (a complete cycle), the amplifier will oscillate. This is because the 'negative feedback' signal, instead of being in opposition to the input signal will actually reinforce it. Thus the input signal keeps getting bigger and bigger - positive feedback occurs. To make sure this can't happen, the open loop gain of the amplifier is shaped either internally (eg. internal compensation in the 741 op-amp) or externally so that at the frequency where the phase shift approaches 360°, the gain is less than unity.

In practice we need to be careful that we don't design a circuit which sets a closed loop gain higher than the op-amp can 'keep up with' at high frequencies. For example, the 741 op-amp has a unity gain bandwidth of 1MHz (i.e. at 1MHz its gain is x1) and its gain rolls off from approximately DC at a rate of x10 per decade. This means that at 100Hz it will typically have a gain of 10,000 times, but at 1000Hz this has dropped to 1000 times. By 10,000Hz it has dropped to 100 times. By 100kHz it has dropped to only 10 times.

Power Supply Rejection Ratio

This is the ratio of change in input voltage to the change in supply voltage. This is the ability of an op-amp to reject power-supply-induced noise, hum and drift. Voltage changes on the supply lines are coupled into the amplifier and appear as part of the input signal. Because of this, the power supply hum and noise at the output will be amplified by the gain of the op-amp. Thus if the op-amp is being used as a unity gain inverter, the hum and noise at the output will be that at the input. If the gain is set high, then it will be amplified accordingly. The figures presented for power supply rejection in the data are for unity gain and will deteriorate in direct proportion to the gain of the op-amp. To give an example:-
If an op-amp has a power supply reaction of 80dB (10,000) times, then a power supply hum level of 1v will only produce a hum level of 0.1mV at the output. However, if the op-amp is used at a gain of 1,000 times, this hum will be amplified 1,000 times as well, producing 0.1v of hum in the output signal. Also, power supply rejection will usually deteriorate at high frequencies.

Latch-up

Latch-up is the 'sticking' or 'locking-up' of the output of an op-amp when the maximum differential input voltage is exceeded. In the latch-up condition, the output is stuck at either the positive or negative maximum output voltage, and the input is ineffective in affecting the output. Most of the modern op-amps such as the 741 have eliminated this problem.

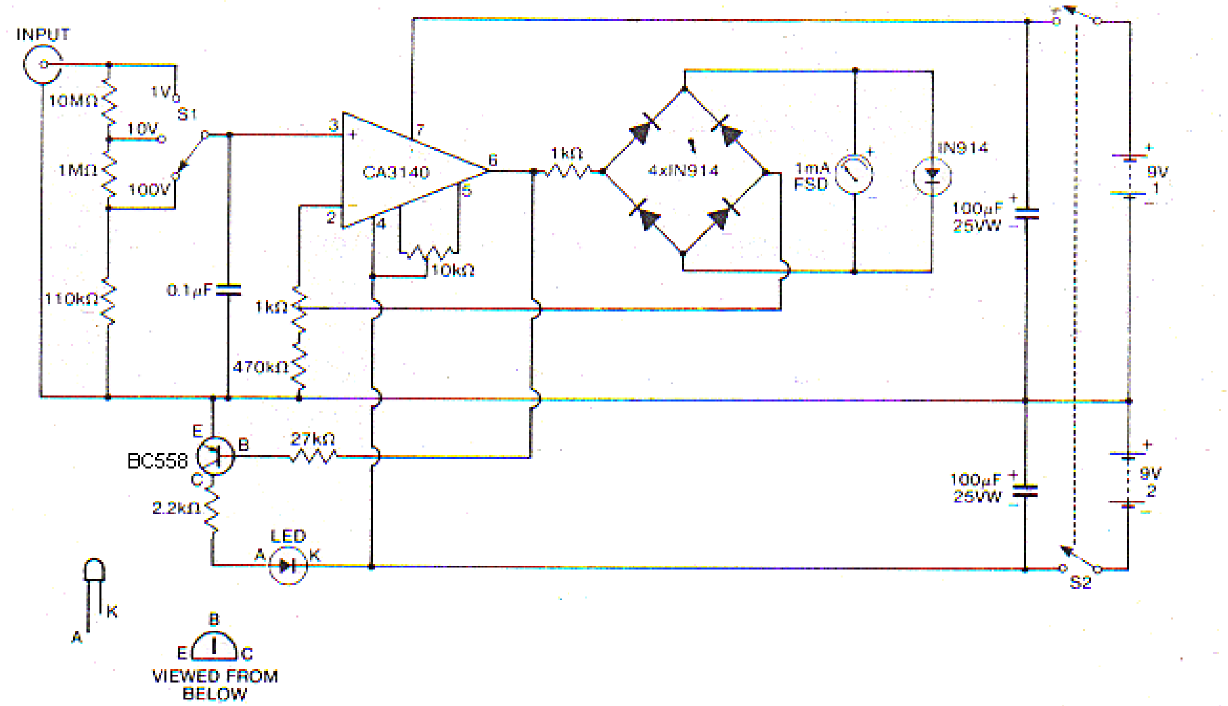
CMOS Operational amplifiers

The CA3130 is a CMOS output operational amplifier, originally designed by RCA. It is a good choice when you want the full output voltage swing to go from rail to rail.
Like the conventional op-amp, the 3130 has an inverting and a non-inverting input. These go to a pair of p-channel MOSFETs set up as a differential amplifier.

Compensation is applied between pins 1 and 8. Compared to the 741, the 3130 has about the same open loop gain and input offset voltage.
The input impedance is about a million times higher ($2x10^{12}$ ohms rather than $2x10^{6}$) and the input bias and offset currents are proportionately lower. Slew rate is about 20 times better, at 10V/µsec. The output of the 3130 is sensitive to capacitive loading. It works on voltages as low as 5v but will only work up to 16v total. Another similar device is the CA3140. It has a bipolar output stage and will work up to a full ±15V. Frequency compensation is internally provided. The output easily drives capacitive loads. It has the same high slew rate and input impedance of the 3130

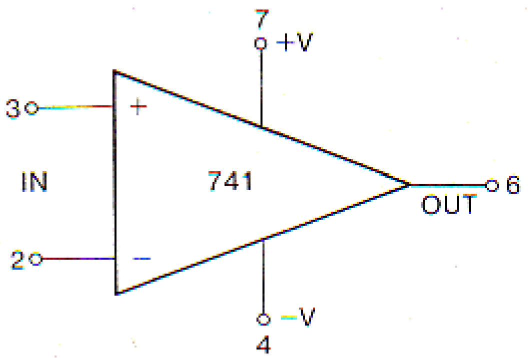
CA3140 High Impedance DC Voltmeter

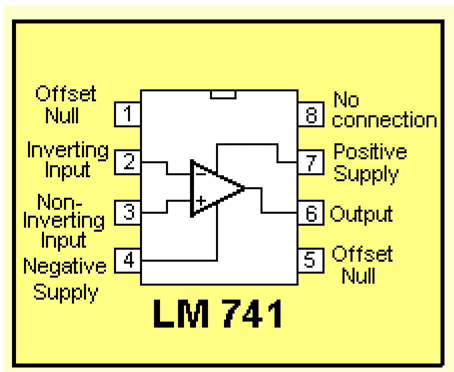
This circuit makes use of the very high impedance of the CA3140 to produce a high performance DC voltmeter with an input impedance of 11M ohms. The instrument uses a cheap 1mA FSD movement and has a diode bridge to correct polarity. If reverse polarity is applied to the instrument, the op-amp biases the BC558 'on' and this turns a LED on.



741 Operational Amplifier

The 741 is a high performance operational amplifier with high open loop gain, internal compensation, high common mode range and exceptional temperature stability. It is short circuit proof and allows for nulling of offset voltage.





Features

- Internal frequency compensation
- Short circuit protection
- Offset voltage null capability
- Excellent temperature stability
- Hign input voltage range
- No latch up

Absolute Maximum Ratings

Supply Voltage	±18v
Internal Power Dissipation	500mW
Differential Input Voltage	±30v
Input Voltage (either input)	± 15v
Output Short Circuit Duration	Indefinite

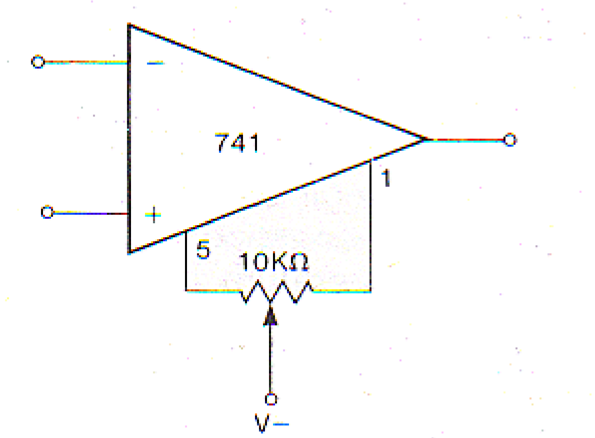
Specifications

Input Offset Voltage	6mV(max)
Input Resistance	2M(typ)
Supply Current	1.7mA(typ)
Large Signal Differential voltage gain	200v/mV(typ)
Common Mode Rejection	90dB(typ)
Supply Voltage Rejection	96dB(typ)
Output Voltage Swing (R_L ≥10k)	±14V(typ)

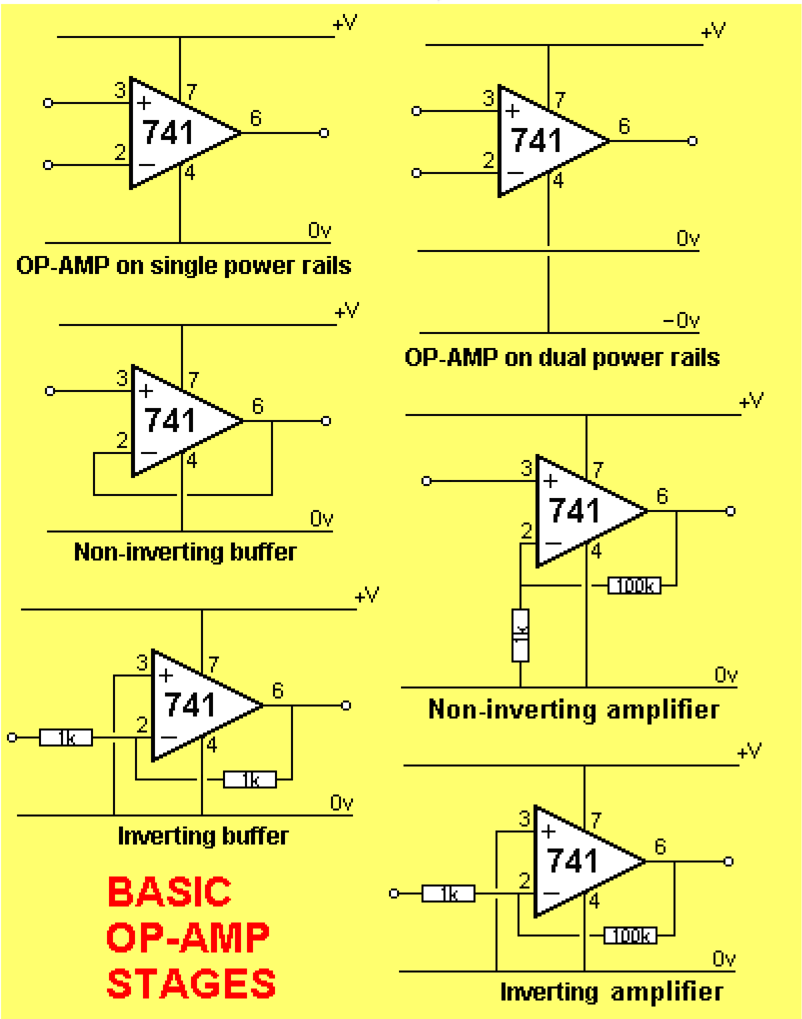
Applications

The 741 is an internally compensated op-amp for unconditional stability. Its gain falls off at 6dB per octave/ 20dB per decade above DC. i.e. as the frequency doubles, the open loop gain halves.
It has a unity gain bandwidth of 1MHz i.e. at 1MHz its gain has dropped to x1.

Offset Adjustment



This can be important in DC circuits or where a high impedance feedback resistor is used. A 10k ohm variable resistor is connected between pins 1 and 5 (of the 8 pin package) and the wiper is taken to - supply.



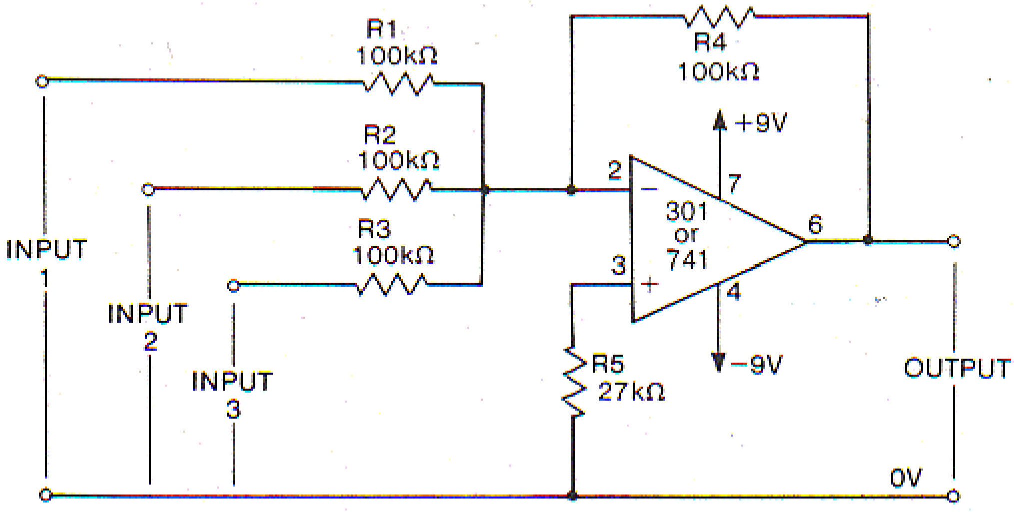
Power Supply Regulation

The 741 can be run on a poorly regulated supply (or one with lots of ripple), but only under certain conditions. Both the 741 and the 301 have a typical supply reaction of 96dB, but this is at unity gain. This decreases with gain. If you are using either op-amp in a high closed loop gain configuration, you must have a well smoothed and regulated supply.

Slew Rate

The 741, when used on ±15V rails will swing to near the full supply rails up to 10kHz. Above this it will be slew-rate-limited, dropping to half the value each octave, i.e. only swing half rail at 20k Hz. This may not matter in audio circuits where the standard output is usually 1.0v RMS, which the 741 can work up to approximately 100kHz.

Audio Mixer

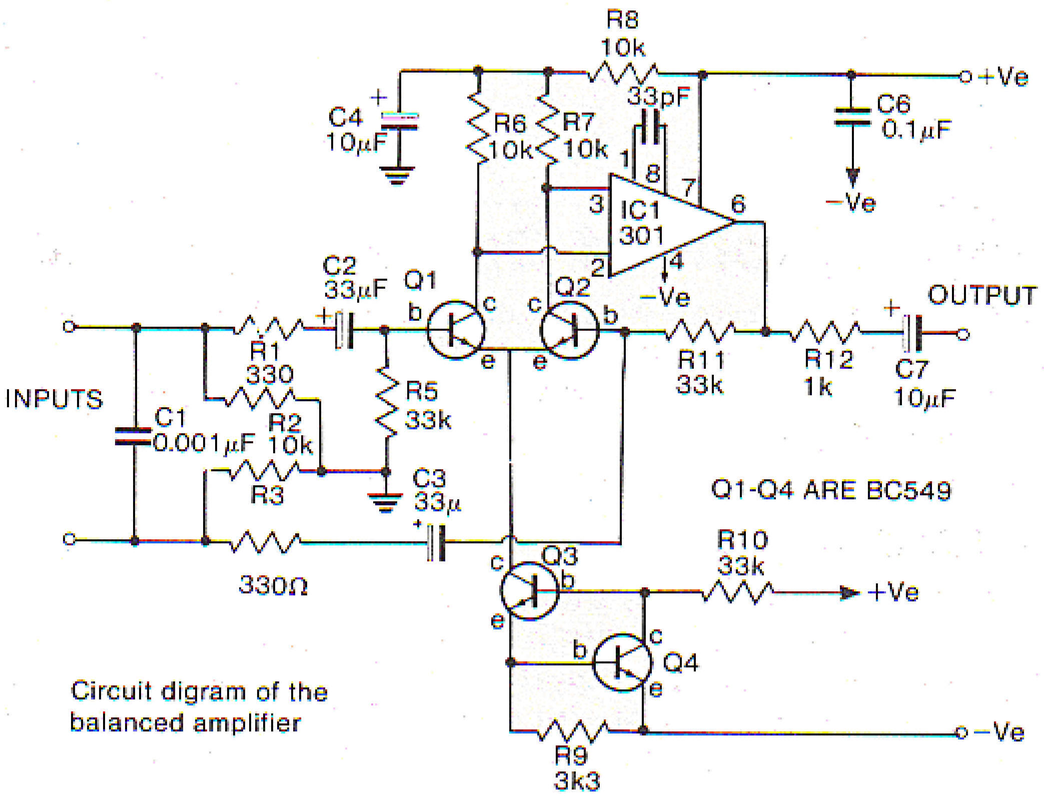


Unity-gain inverting d.c. adder, or 'audio mixer'.

This circuit is for a unity gain inverting adder. The output voltage will be equal to the sum of the three input voltages. While the circuit is shown with only three inputs, more could be added if necessary. This circuit is called a virtual earth input mixer since pin 2 (the inverting input) is seen as 'earth' by the input signals. As a result the input impedance is set by the input resistors and there is very little interaction between inputs. It this is used as an audio mixer, it is a good idea to wire capacitors between the inputs and their signals and also on the output. 1uF tantalum would be a good value.

Difference Amplifier

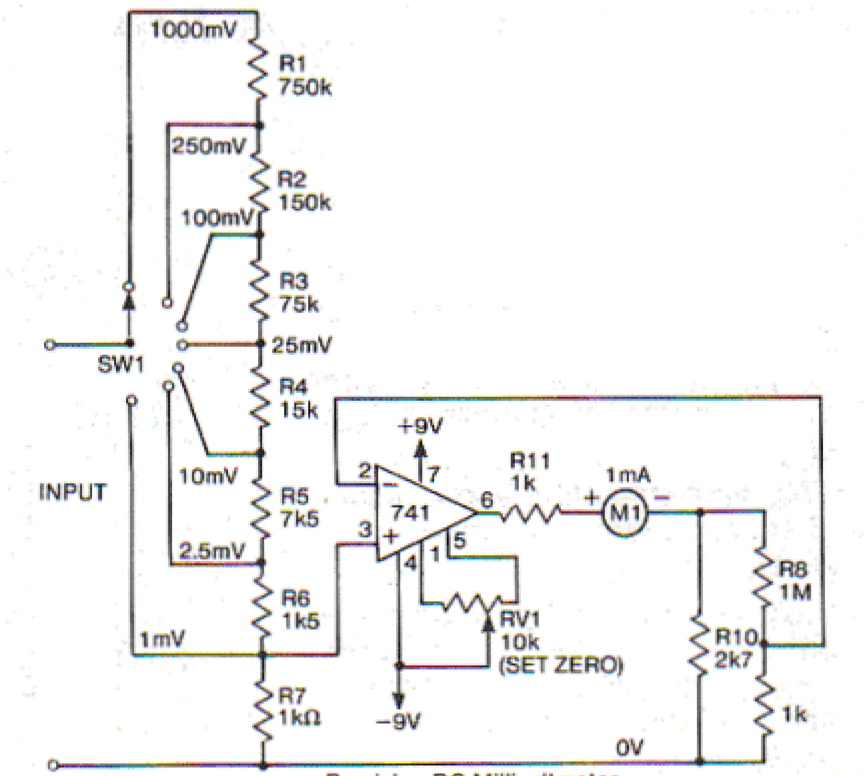
The circuit below shows a typical application for a unity gain difference amplifier- a balanced input audio amplifier. The output is the difference between the two input signals. These circuits are often used in audio when long leads must be run - say between a microphone and an audio mixer. Signals such as hum or buzz from lighting controllers (triac dimmers are renowned for their electrical 'noise' producing ability!) are picked up along the cable. The difference amplifier gets this signal equally on both inputs and cancels it out. The good 'wanted' signal will be seen as a difference at the input terminals and will be passed through.



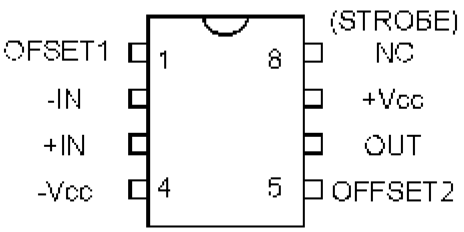
Circuit digram of the balanced amplifier

Precision DC Millivoltmeter

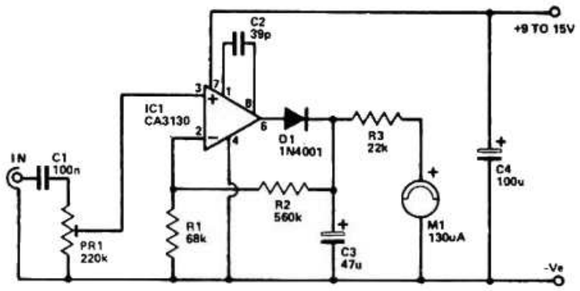
The very high DC performance of the 741 and 301 make them ideal for DC measuring equipment. The circuit following is for a precision DC millivoltmeter. It will give full scale voltage readings from 1mV to 100mV in seven ranges.



Precision DC Millivoltmeter

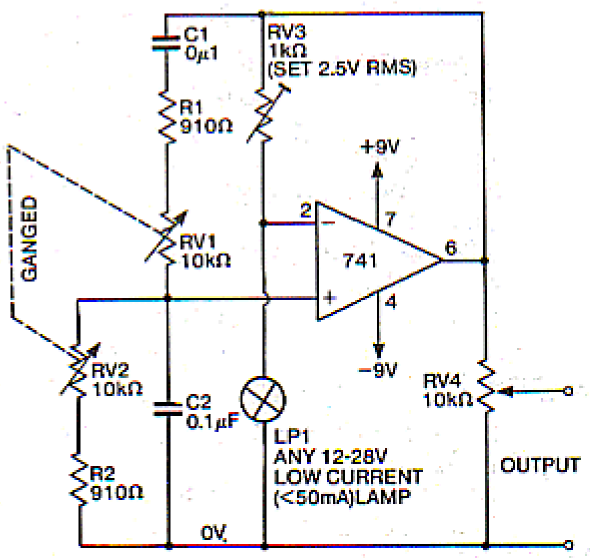


CA 3130 OP-AMP



Peak reading VU Meter

Wein-Bridge **Oscillator**



150Hz - 1.5Hz Wein-bridge oscillator

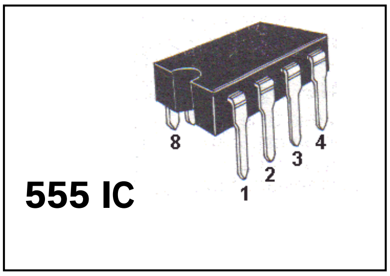
The circuit shows how the 741 or 301 can be connected as a variable frequency Wein-Bridge oscillator. As it stands, the circuit covers from 150Hz to 1.5kHz and uses only a cheap miniature globe for amplitude stabilization. Output is approximately 2.5V RMS and distortion less than 0.1 %. The frequency is inversely proportional to the values of C, and C_2 and can be varied to work up to about 25kHz.

555 Timer

The 555 is a highly stable device designed for generating accurate time delays or oscillations. Additional terminals are provided ' for triggering or resetting. In the time delay mode (monostable mode) the time is set by one external resistor and one capacitor. In the astable (free running) mode the frequency and duty cycle are set by two external resistors and one capacitor. The circuit can be both triggered and reset on falling waveforms. The output circuit can source or sink up to 200mA. TTL circuitry can be driven directly from the output.
A dual version of this IC is available, the 556.

Features

- Timing from microseconds to hours
- Adjustable duty cycle
- Sink & source 200mA
- 4-15V operation
- Temperature stability >0.005% per°C

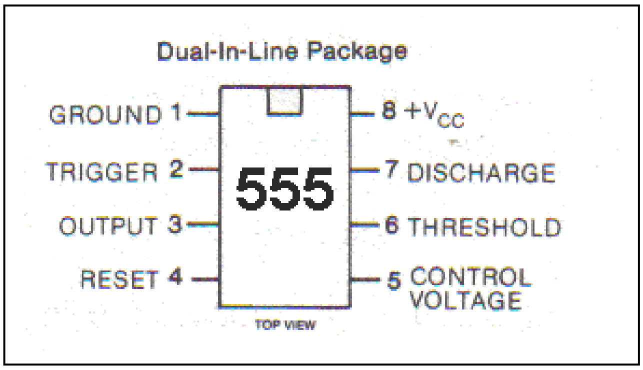


Absolute maximum ratings

Supply	+18V
Power dissipation	600mW

Specifications

Timing Error, monostable Temperature drift		50ppm/°C
Supply Drift		0.1 %/V
Timing Error, astable Temperature Drift		150ppm/°C
Supply Drift		0.30%/V
Trigger Voltage		
V_{cc} 15V (I_{trig} = 0.5µA)	5V	
V_{cc} 5V	1.67v	
Control Voltage		
V_{CC}15V	10v	
V_{CC} 5V	3.3v	



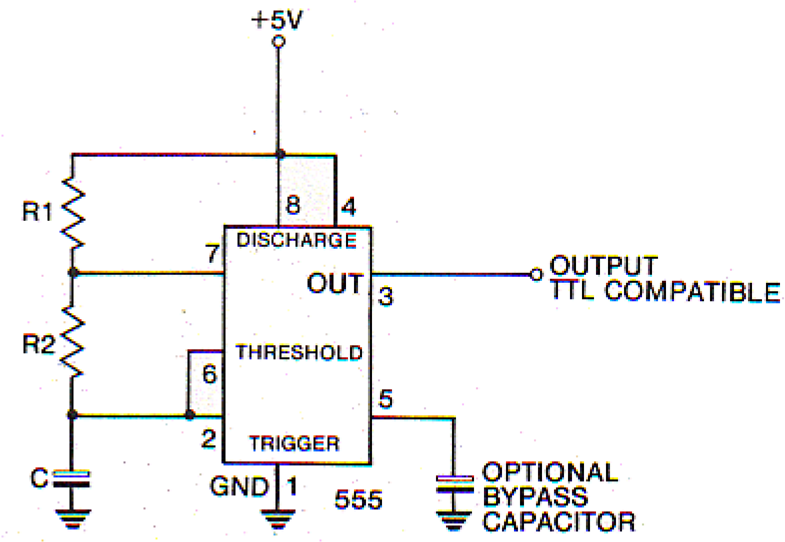
555 Modes & uses

Free-running: astable multivibrator

When powered from a 5v supply the 555 is directly compatible with TTL. It can also run from 4-15v and can source and sink several hundred milliamps at its output.
One end of the timing capacitor is connected to ground, the other to the positive supply via resistor(s) allowing the use of electrolytics.
The high input impedance allows the use of large resistors and small capacitors. Up to 1000:1 frequency range can be obtained from a single capacitor by changing the resistance timing element.

Astable operation

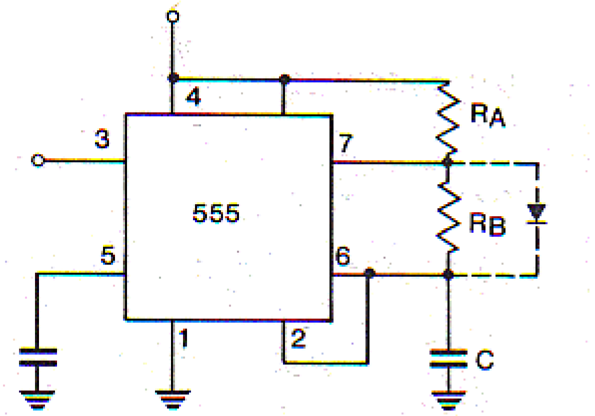
1. Output (pin 3) is high
2. Charge on capacitor is low
3. Discharge transistor not conducting
4. Capacitor starts to charge
5. When voltage across the capacitor reaches two-thirds of the supply voltage the comparator triggers. Output goes low, capacitor is discharged via R_2. When the voltage on the capacitor drops to one third of the supply the comparator flips the circuit back. Then the whole sequence repeats for the next cycle.



If R_2 is made large compared to R_1, output is low but symmetry of waveform is high.

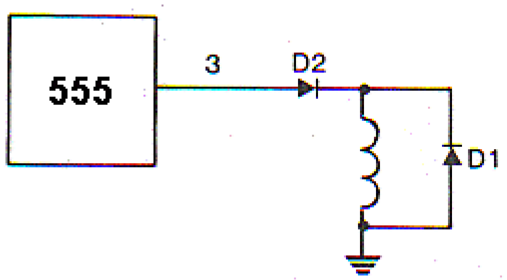
Altering the Duty Cycle

The duty cycle is the 'on' time as a percentage of total cycle time. This is normally limited to 50%. By adding a diode, a duty cycle of less than 50% can be achieved.



Curing Latch-up problems

Latch-up when driving an inductive load can be avoided by adding two diodes as shown in the circuit below. This stops negative voltage from reaching pin three.



Fine Control of Timing/Frequency

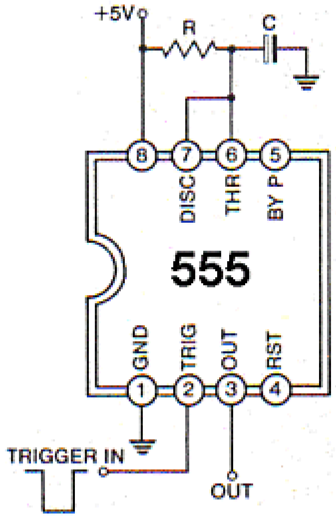
Pin 5, the control pin, is primarily used for filtering when the device is used in noisy electrical environments. However, by putting a voltage on this point, it is possible to vary the timing of the device independently of the 'RC' components. This control voltage may be varied from 45% to 90% of supply voltage in the monostable mode and from 1.7V to V_{cc} (supply voltage) in the astable mode.

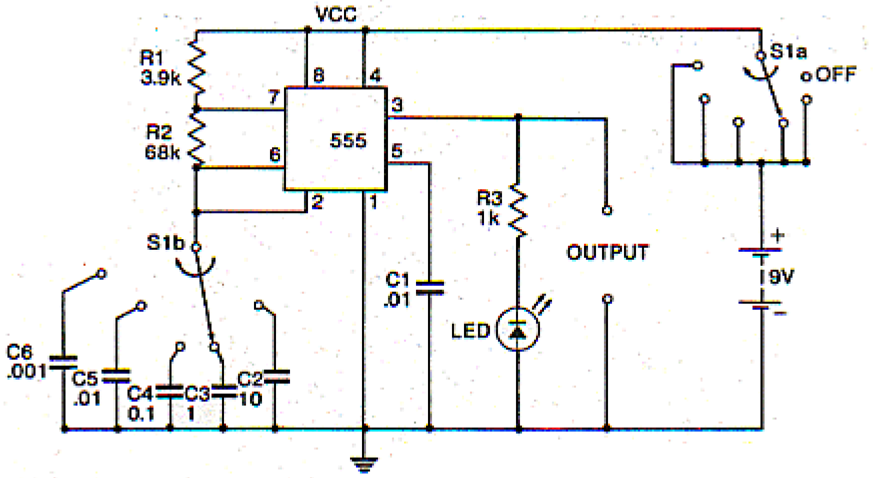
Monostable operation

1. Bringing trigger from +V to ground starts sequence.
2. Output goes positive.
3. Clamp is removed from timing capacitor which then charges to two thirds of supply voltage. The threshold comparator then flips the circuit over. Output goes to ground and the capacitor is rapidly discharged to ground.

Square Wave Oscillator

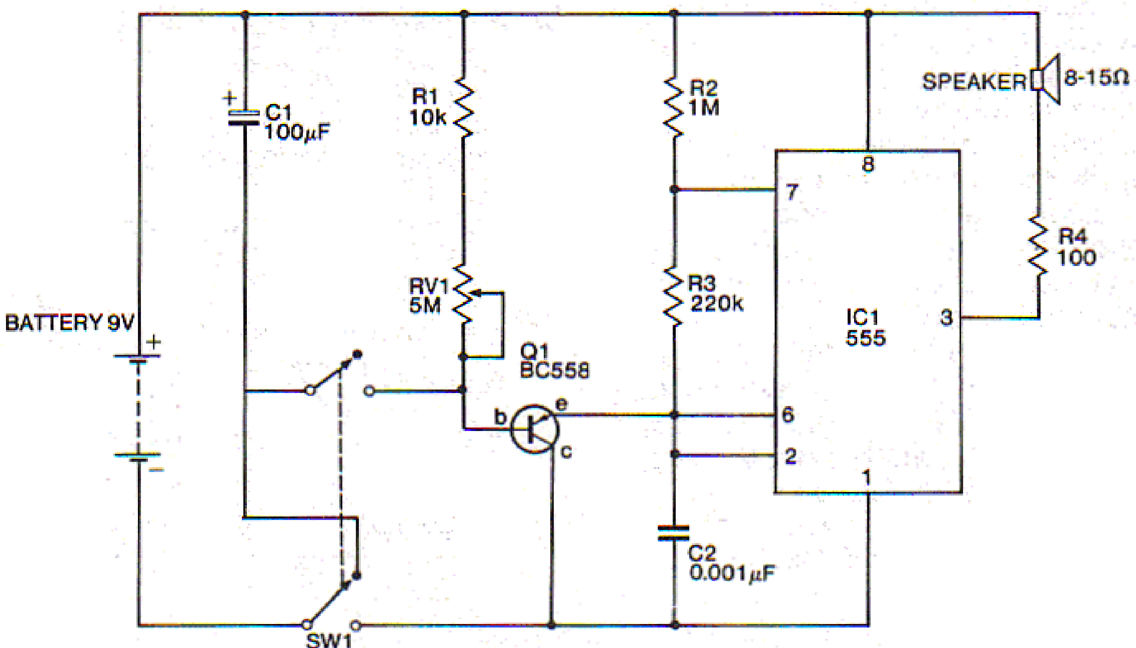
This simple circuit provides square waves at five switched frequencies from 1Hz to 10kHz. It uses the 555 in the astable mode.





Timer circuit

This circuit produces a warning tone after a preset period. The delay period is controlled by C_1/R_1 and RV_1 and can be adjusted from a few milliseconds to approximately 500 seconds. The 555 is normally "switched off". C_1 discharges via R_1 and RV_1. When it has discharged, the 555 is turned 'on' via Q_1 and oscillates, producing a warning tone.



TIMER CIRCUIT

Special Version of the 555

ICM7555

The ICM 7555 is a CMOS timer IC providing significantly improved performance over the standard 555 timer. At the same time it will act as a direct replacement for this device in most applications. Improved parameters include the low supply current, wide operating supply voltage range, low *threshold, trigger* and *reset* currents, no crowbarring of the supply current during any output transition, higher frequency performance and no requirement to decouple the *control voltage* for stable operation. A dual version of the 7555 is available, the 7556, with two timers sharing only V+(V_{CC}) and V-(GND). They are both capable of sourcing and sinking sufficient current to drive TTL loads and have small enough offset to drive CMOS loads.

Features

- Low supply current (80µA typ)
- Ultra low trigger threshold. (20pA typ)
- High speed operation (500kHz guaranteed)

- Wide supply range 2v to 18v
- No crowbarring of supply during reset.
- Can be used with higher impedance timing elements than 555.
- Complete static protection.

Absolute Maximum Ratings

Supply Voltage	+18v
Input Voltage	
Trigger	Supply + 0.3V
Threshold	Supply - 0.3V
Reset control voltage	
Output Current	100mA
Power Dissipation	200mW

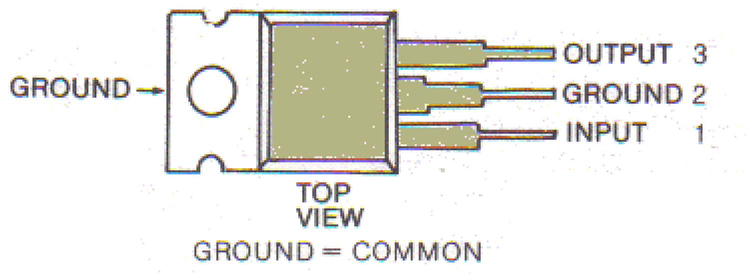
Specifications

Supply Voltage	2v to 18v
Supply Current	60-120uA
Timing	
Initial Accuracy	2.0%
Drift with temperature	50ppm/°C
Drift with Supply Voltage	1%/V
Trigger Current @ Supply Voltage 5V	10pA
Reset Current @ Supply Voltage 5V	20pA
Maximum Oscillator Frequency	500kHz

Trigger and Threshold Voltages are as for the standard 555.

LM340 and 78XX series 3 terminal regulators_LM340T5, 12, 15 7805, 7812, 7815

The LM340 series of positive 3 terminal regulators offer similar performance to the 78XX series. They are complete voltage regulators with outstanding ripple rejection and superior line load regulation.
Current limiting is included to limit peak output current to a safe level. Safe area protection for the output transistor is provided. If internal power dissipation is too high, thermal shutdown occurs. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

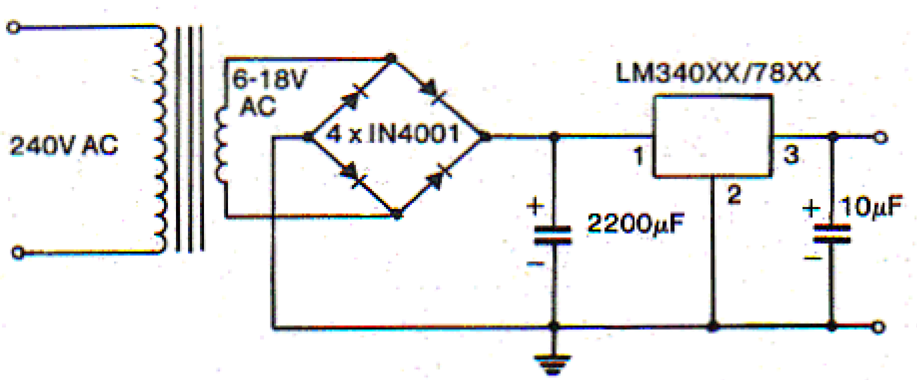


Features

- Maximum 1A output
- Output voltage tolerance ±2%
- Load regulation 0.3%
- Thermal overload protection
- Short circuit current limit
- Output transistor safe area protected
- Continuous dissipation 15W

Basic use as a fixed regulator

The 10µF capacitor across the output is needed for stability and improves the transient response of the supply.



Specifications @ 25°C

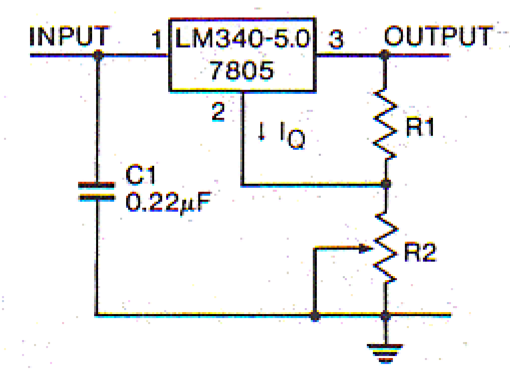
	μA7805/ LM340T-5	μA7812/ LM340T-12	μA7815/ LM340T-15
Output voltage	5v ± .25	12v ± .6	15V ±.6
Ripple rejection	80dB	72dB	70dB
Input voltage (minimum to maintain line regulation)	7.3v	14.5v	17.5v
Dropout voltage	2.0	2.0	2.0
Peak output current	2.2A	2.2A	2.2A
Short circuit current	2.1A max	1.5A max.	1.2A max.
Load regulation (5mA to 1.5A)	12mV typ.	12mV typ.	12mV typ.
Bias current	8mA max	8mA max	8mA max
Absolute max input voltage	35v	35v	35v

Applications

Apart from the normal use as a fixed voltage regulator, the LM340/78XX can be used in a variety of ways with the addition of external circuitry.

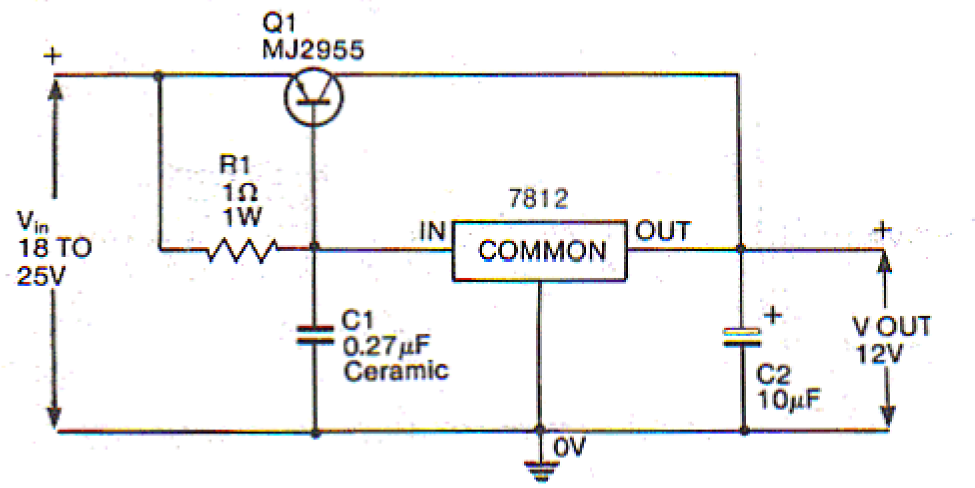
Adjustable output

This simple circuit gives the LM340T-5 variable output voltage according to the formula:
$Vout = 5v + (5v/R1+I_Q)R2$



Boosting the current output of the LM340T/ 78XX series

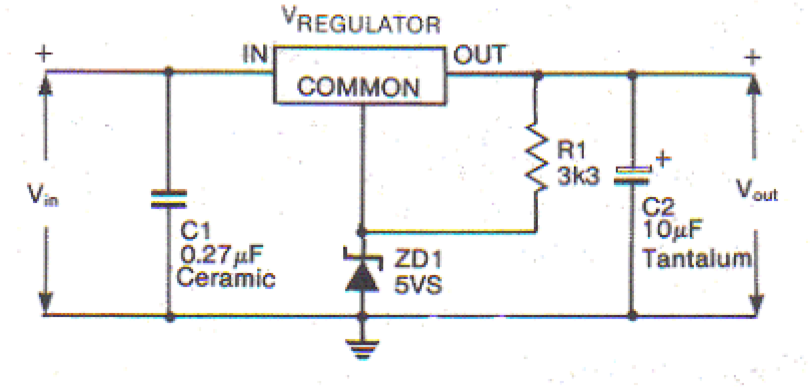
This circuit supplies regulated outputs at up to 5A. At low currents Q1 is off. Only above 600mA is it biased on.



Providing fixed higher voltages

The output voltage of the LM340T/78XX series can be increased over the standard voltage of the regulator by using a zener diode in the common to earth lead.

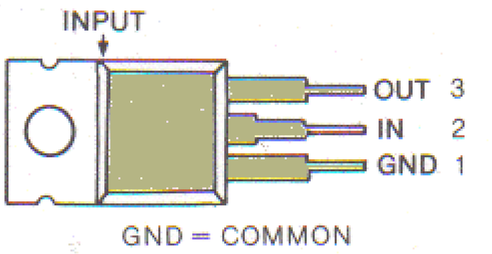
$V_{OUT} = V_{ZENER} + V_{REGULATOR}$



79XX three terminal negative voltage regulators

The 79XX series are three terminal negative regulators with fixed output voltages. The only external component necessary is a compensation capacitor on the output.

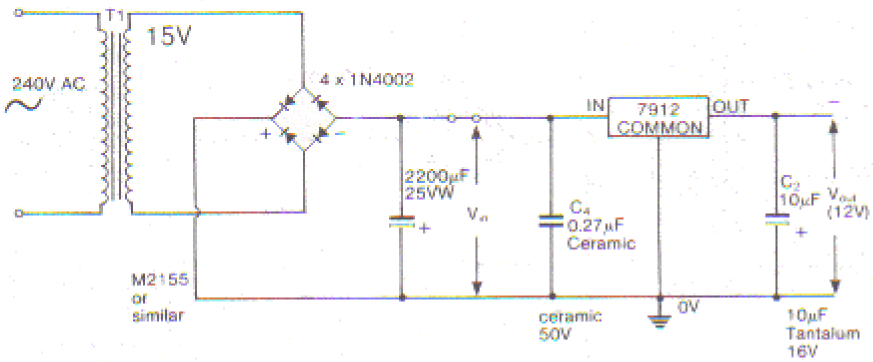
These are essentially similar to the 78XX series positive regulators, with current limiting and thermal overload protection.



Specifications @25°C

	LM7905	LM7912	LM7915
Output Voltage	-5v ±.2	-12v ±.5	-15v ± .6
Line regulation	5mV typ	5mV typ	5mV typ
Quiescent Current	1mA	1.5mA typ	1.5mA typ
Power dissipation	1.5W	1.5W	1.5W
Input voltage maximum	-35v	-35v	-35v
Minimum input voltage	7v	14.5v	17.5v

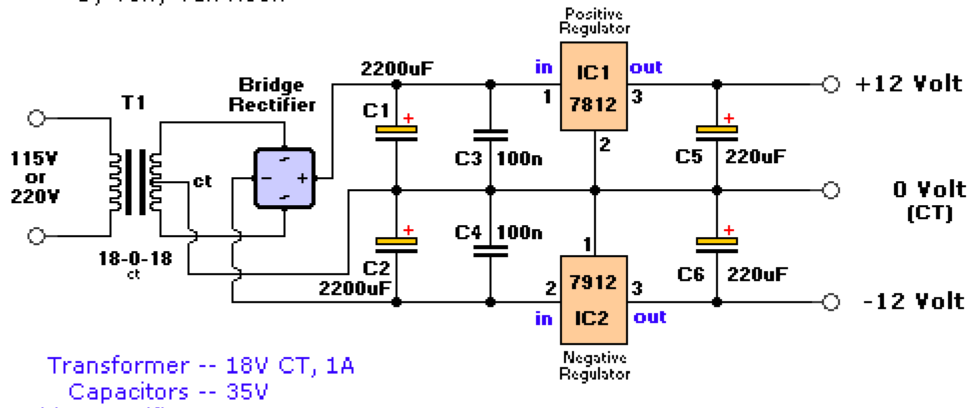
Standard circuit



Dual Voltage Power Supply

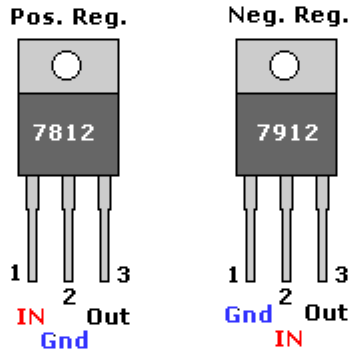
by Tony van Roon

The use of a pair of the regulators (positive and negative) makes an ideal dual rail supply, for powering op-amps etc. A suitable circuit is shown below. This one uses 12V regulators, but obviously the voltage can be varied by changing regulators.



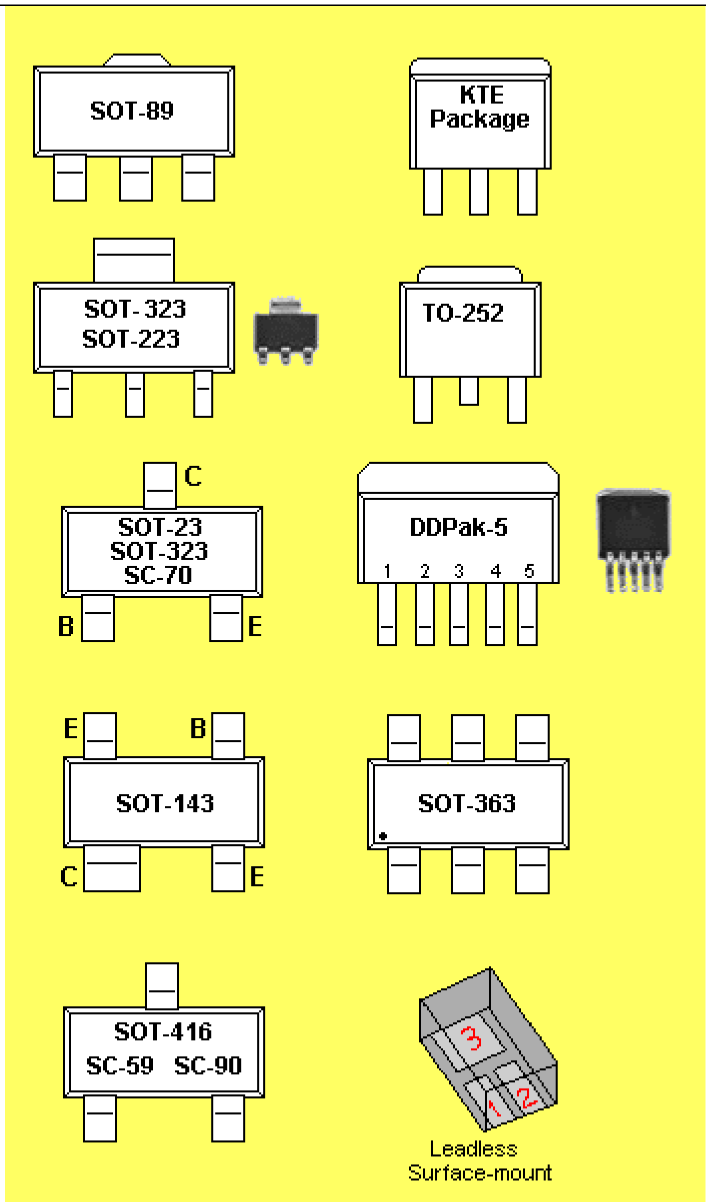
Transformer -- 18V CT, 1A
Capacitors -- 35V
Bridge Rectifier -- 100V, 2A
C3,C4 -- Ceramic, 50V

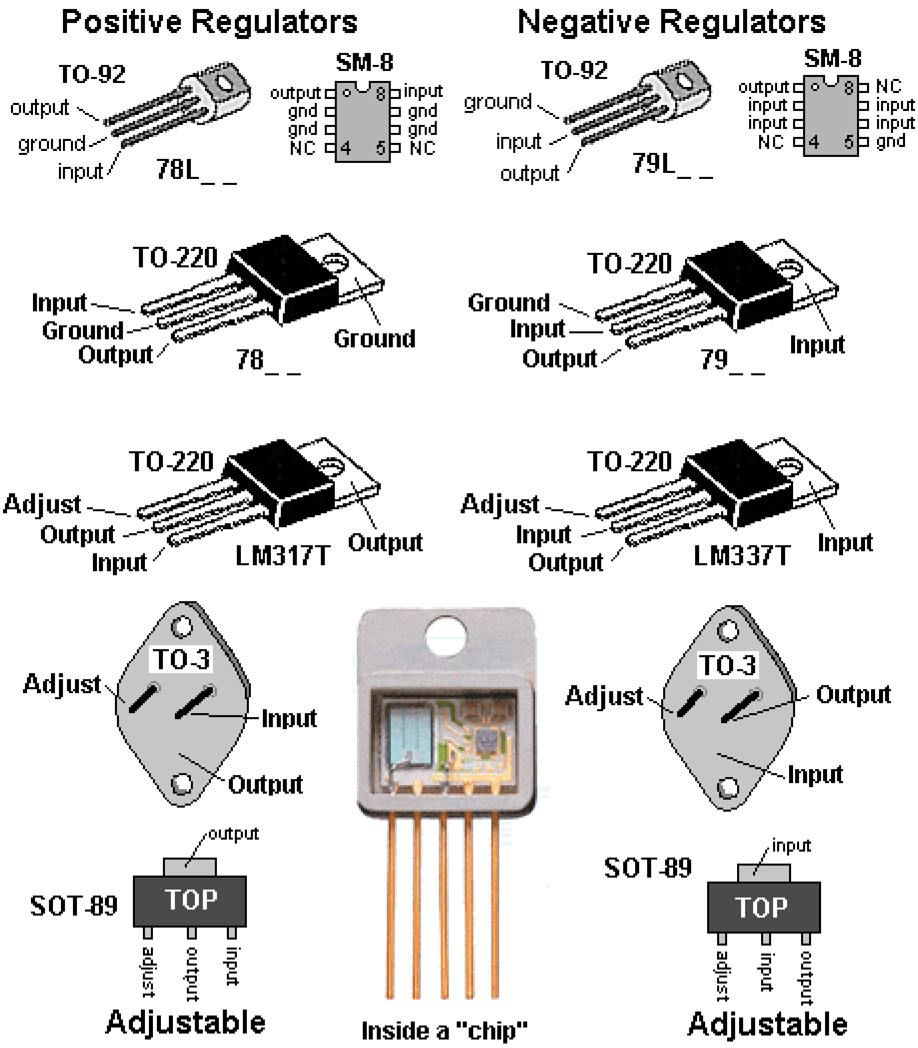
Caution: Input/Ground are reversed between the 7812 and 7912.

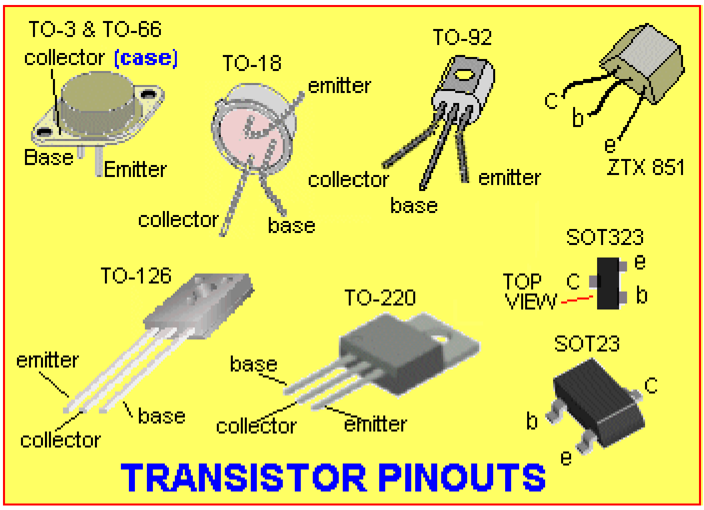


This list is only some of the most common types:

Device	Voltage	Current	Pinout
7805	+5v	1A	TO-220 positive
78L05	+5v	100mA	TO-92 positive
7806	+6v	1A	TO-220 positive
7808	+8v	1A	TO-220 positive
7810	+10v	1A	TO-220 positive
78L12	+12v	100mA	TO-92 positive
7812	+12v	1A	TO-220 positive
78S12CT	+12v	2A	TO-3 positive
7818	+18v	1A	TO-220 positive
7824	+24v	1A	TO-220 positive
7905	-5v	1A	TO-220 negative
79L05	-5v	100mA	TO-92 negative
7906	-6v	1A	TO-220 negative
7908	-8v	1A	TO-220 negative
7912	-12v	1A	TO-220 negative
79L12	-12v	100mA	TO-92 negative
7915	-15v	1A	TO-220 negative
7918	-18v	1A	TO-220 negative
7924	-24v	1A	TO-220 negative
LM317T	+1.2V to +37V	1.5A	TO-220 adjustable
LM337SP	-1.2V to -37V	1.5A	TO-220 adjustable
LM123k	+5v	3A	TO-3 positive
LM117K	+1.2V to +37V	3A	TO-3 positive



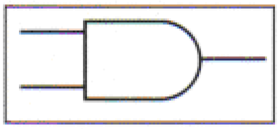

Positive Regulators
Negative Regulators
TO-92
output
ground
input
78L_ _
SM-8
output
gnd
gnd
NC
input
gnd
gnd
NC
TO-92
ground
input
output
79L_ _
SM-8
output
input
input
NC
NC
input
input
gnd
TO-220
Input
Ground
Output
Ground
78_ _
TO-220
Ground
Input
Output
Input
79_ _
TO-220
Adjust
Output
Input
Output
LM317T
TO-220
Adjust
Input
Output
Input
LM337T
TO-3
Adjust
Input
Output
TO-3
Adjust
Output
Input
SOT-89
output
TOP
adjust
output
input
Adjustable
Inside a "chip"
SOT-89
input
TOP
adjust
input
output
Adjustable


TO-3 & TO-66
collector (case)
Base
Emitter
TO-18
emitter
collector
base
TO-92
collector
base
emitter
c
b
e
ZTX 851
SOT323
TOP VIEW
c
e
b
TO-126
emitter
base
collector
TO-220
base
collector
emitter
SOT23
c
b
e
TRANSISTOR PINOUTS

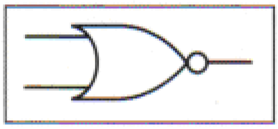
Logic Gates

OR Gate: Output is a logic "0" only if both inputs are "0". A logic "1" at either or both inputs produces a logic "1" output.

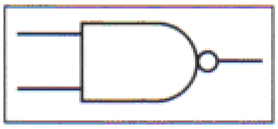
AND Gate: Output is a logic "1" only if both inputs are "1". A logic "0" at either or both inputs produces a logic "0" output.



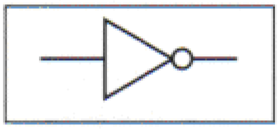
NOR Gate: Output is a logic "1" only if both inputs are "0". A logic "1" at either or both inputs produces a logic "0" output.



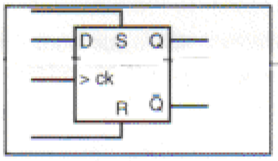
NAND Gate: Output is a logic "0" only if both inputs are "1". A logic "0" at either or both inputs produces a logic "1" output.



Inverter or NOT gate: Output is a logic "1" when input is "0". Output is a logic "0" when input is "1". ie Inverts the input state.



D Flip-Flop: Transfers the input at D to the output at Q (and it's inverse to Q-bar), on the rising edge of the clock signal at C. No change in any outputs on the falling edge of the clock pulse.



AND

A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

OR

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

NAND

A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0

NOR

A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

BUFFER

Input	Output
0	0
1	1

NOT Inverter

Input	Output
0	1
1	0

XOR

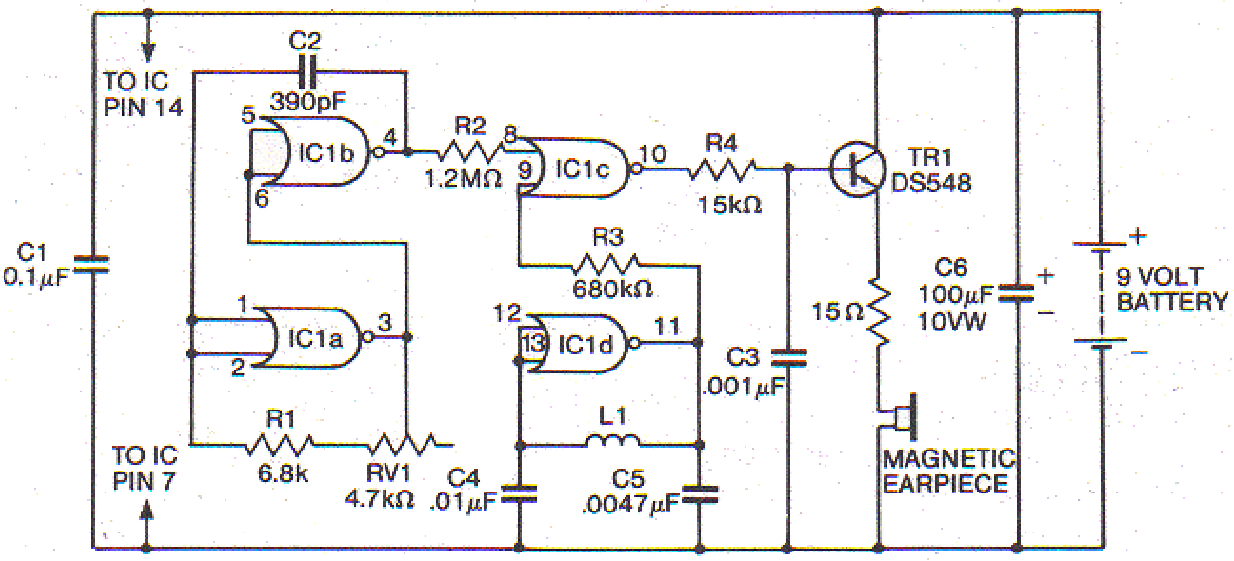
A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0

exclusive-OR

The above tables are called TRUTH TABLES. They give all the possible outcomes for a particular gate.
The inputs are labeled A and B as shown above and the output is the result of the inputs at HIGH or LOW level.
A HIGH is “1” and a LOW is “0.”

4001 Metal Detector

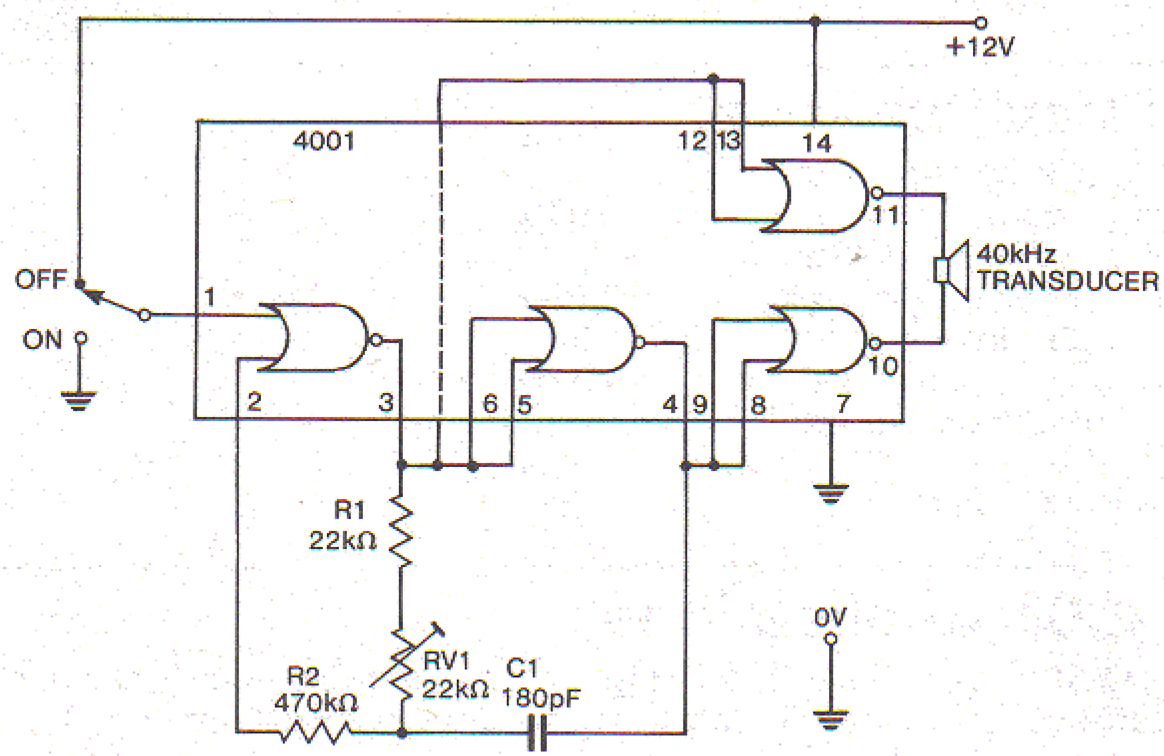
4001 is used in this circuit as two different types of oscillator. IC1a and IC1b with R_1, RV_1 and C_2 form one oscillator. RV_1 varies its frequency slightly. lCl_d, C_4, C_5 and L_1 (search coil) form the second oscillator. $IC1_8$ acts as a mixer, combining the two oscillators and producing an output which is the difference between the two. This is amplified by TR_1 and fed to a magnetic earpiece.



L1. 18 METRES HOOK UP WIRE WOUND ON 140mm DIA. FORMER

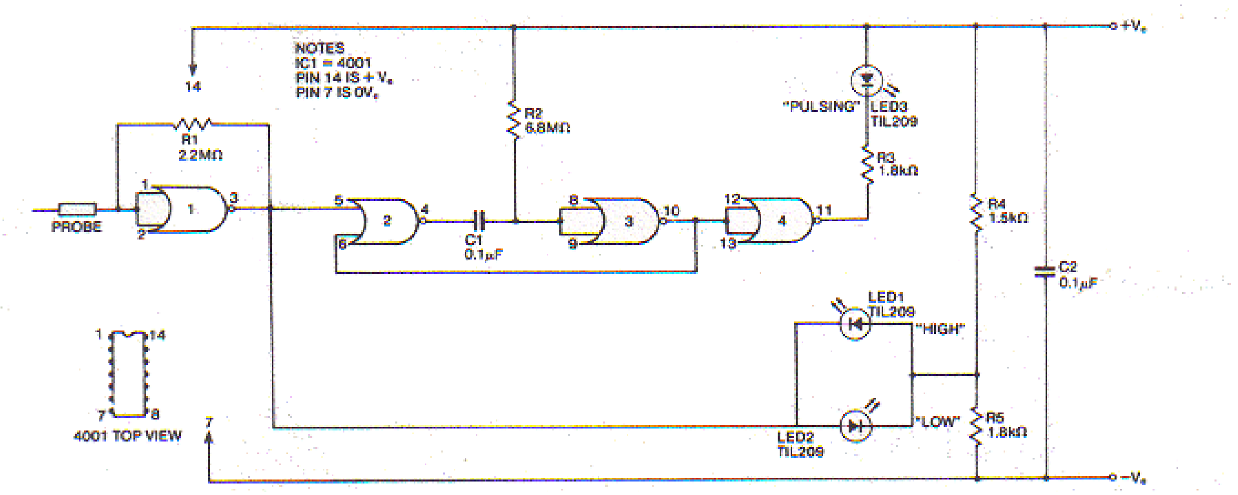
Ultrasonic Transmitter

The 4001 forms a complete 40kHz oscillator and driver for an ultrasonic transmitter. The oscillator frequency can be adjusted by means of RV_1. Two gates act as square wave oscillators which then drive the other two gates in push-pull. These drive the transducer in push-pull to get the maximum.



CMOS Logic Probe

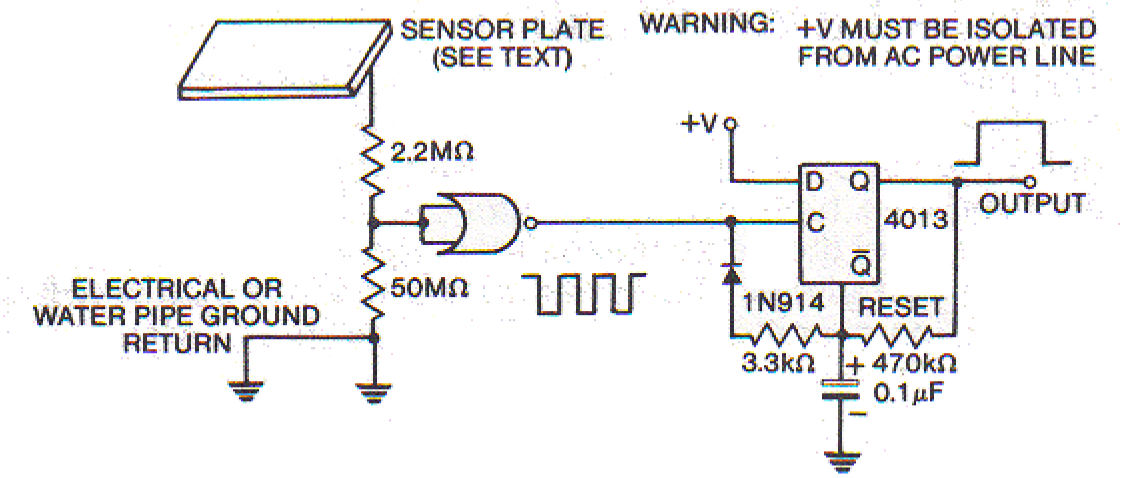
The logic probe is an essential instrument for testing digital circuitry. This one uses only one 4001 IC, 3 LEDs and a handful of passive components. Power is obtained from the circuit to be tested. The first gate acts as an inverter by strapping its two inputs together. It is biased for half supply by R_1. Under quiescent conditions neither LED1 or LED2 will light. If the input goes high, gate output goes low and LED1 comes on. If the input is taken low, the output of IC1 goes high and LED2 comes on, indicating a low signal. Short pulses are 'stretched' by IC gates 2 and 3, producing a flickering output at LED3.



Touch Switch

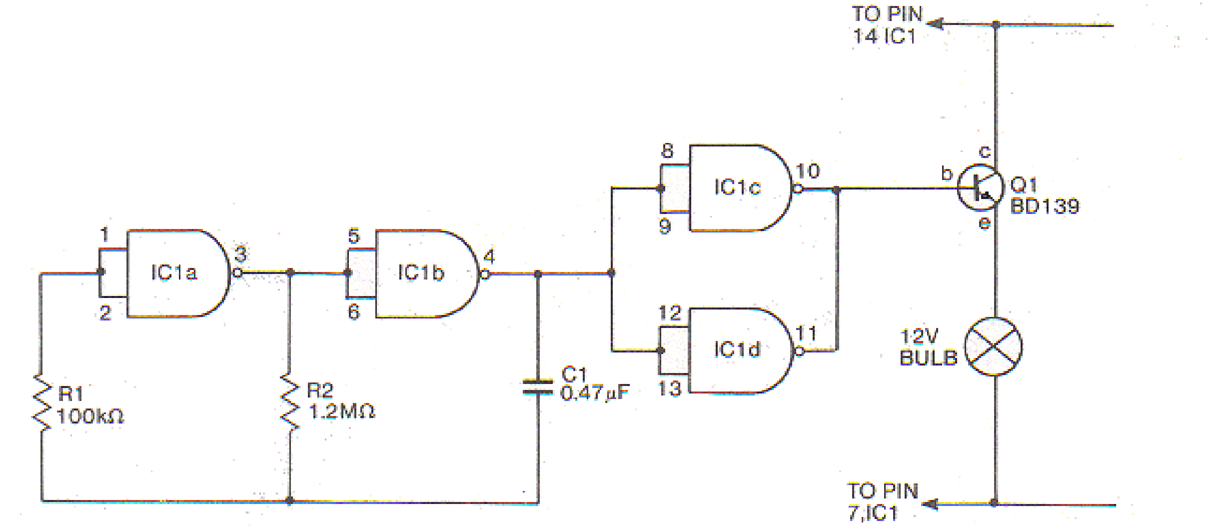
The near infinite input impedance of CMOS makes it ideal for use in touch and proximity circuits. Usually a touch sensitive circuit needs physical contact, while proximity circuit needs only the presence of an object such as the human body. Touch sensors rely on three features of the human body. Skin resistance is usually a few hundred thousand ohms, the body has a capacitance to earth of around 300pF and the human body acts as an antenna, picking up 50Hz power line fields. The figure below shows a proximity switch based on human coupling of the 50Hz power line. A hand very near the plate will induce hum onto the plate and this will be passed to the circuit. The first gate is a 4001 with both inputs strapped together. The hum will be squared up and used to trip the retriggerable monostable as shown. A clean output results from the instant of first proximity until a few milliseconds after release. The sensitivity depends on the size of the plate.

The output of the 4013 can be connected to a relay via a transistor. It could then be used to turn on a light or other piece of electrical equipment. The 50M resistor can be made by putting 5M resistors in series.

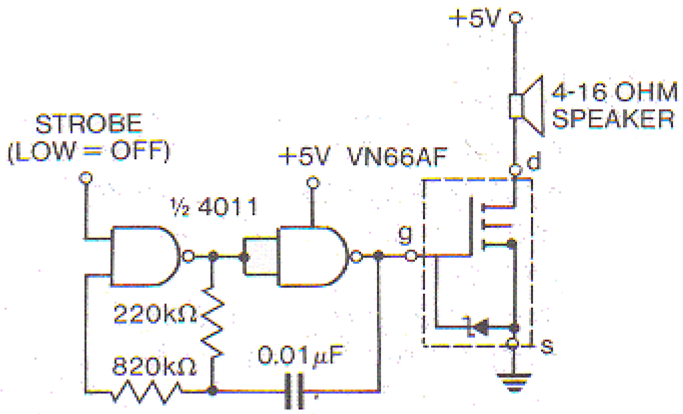


CMOS Lamp Flasher

This circuit uses the four CMOS NAND gates of the 4011 as an oscillator and low power driver. The first two form a low frequency oscillator. All the gates are used with their inputs connected together. In this form they act as an inverter i.e. a HIGH produces a LOW out. The very high input impedance of the gates means that high impedance values can be used in the oscillator circuit. The power consumption is also very low and the circuit will function over the normal 3-15 volts range of CMOS.



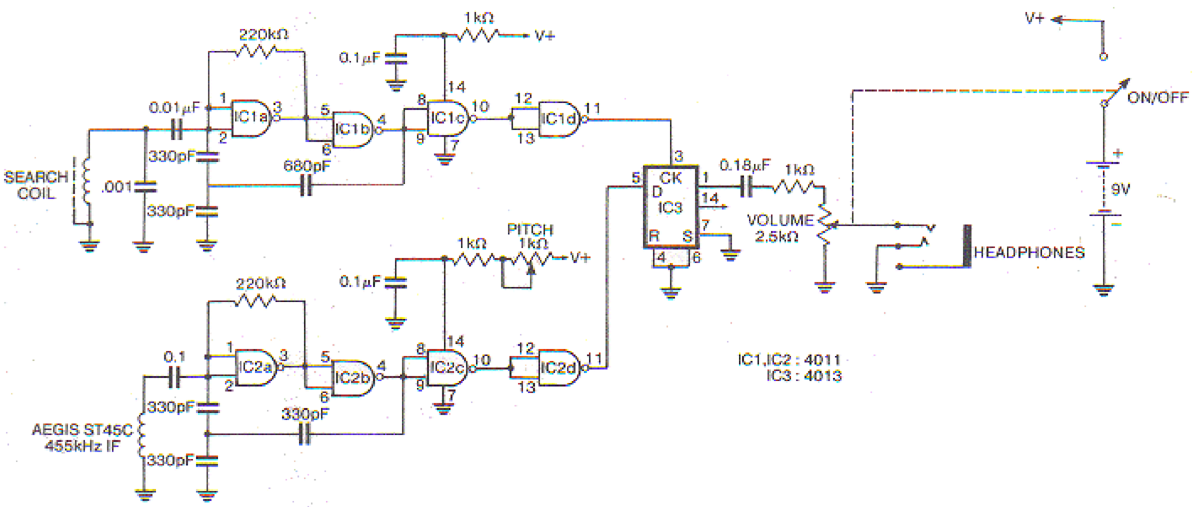
Audio Alarm



The addition of a VFET driver transistor following a CMOS oscillator makes a very efficient and simple audio alarm. As well as this it will drive a low impedance speaker directly.

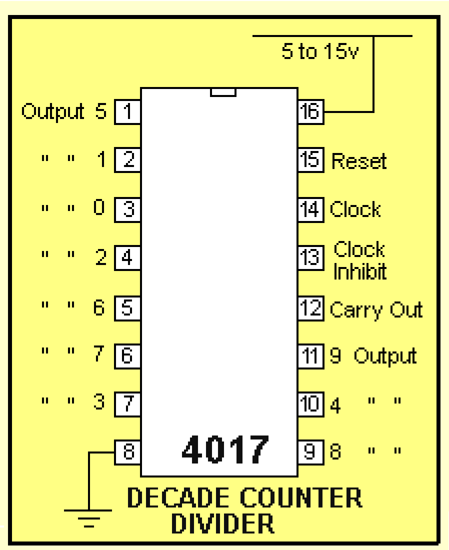
Metal Detector

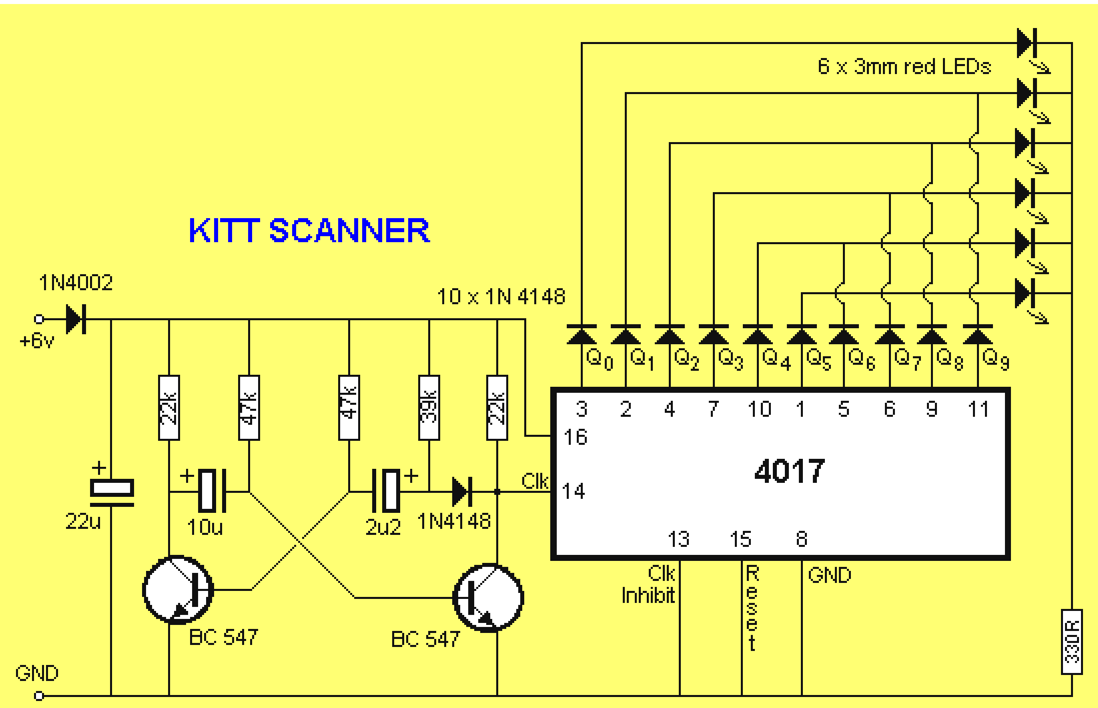
This unit uses two pairs of 4011 NAND gates as two oscillators and two 4011 buffers. The search coil oscillator has its frequency influenced by the position and proximity of metal at the search head. The reference oscillator has its frequency adjusted by the slug tuning of its coil and fine tuning by adjusting the voltage on IC2c. The two signals are digitally mixed in one section of a dual D-type flip-flop.



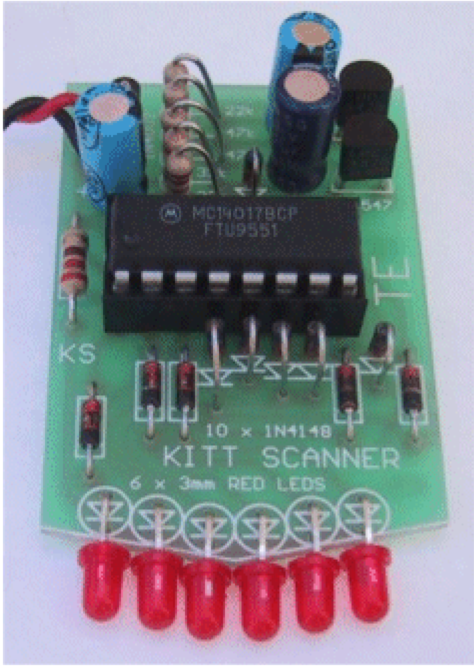
4017 CMOS Decade Counter/ Divider with 10 Decoded Outputs (Johnston Counter)

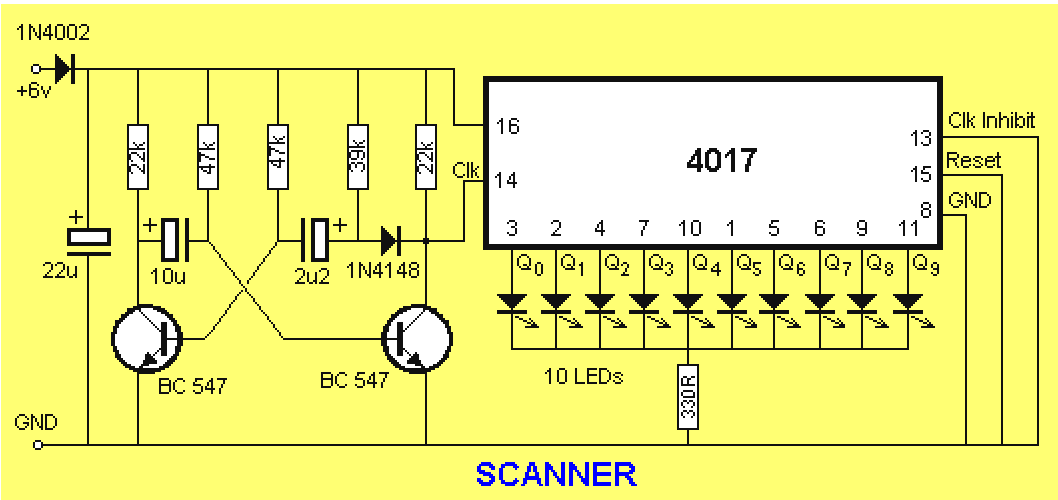
The CD 4017 is called a COUNTER or DIVIDER or DECADE COUNTER. It is a very handy chip for producing "Running LED effects" etc.
It has 10 outputs. For normal operation, the clock enable and reset should be at ground.
Output "0" goes HIGH on the rise of the first clock cycle.
On the rise of the second clock cycle, output "0" goes LOW and output "1" goes HIGH. This process continues across the ten outputs and cycles to output "0" on the eleventh cycle.
The "Carry Out" pin goes LOW when output "5" goes HIGH and goes HIGH when output "0" goes HIGH.
In other words, "Carry Out" is HIGH for outputs 0, 1, 2, 3 and 4. It is LOW when the following outputs are active: 5, 6, 7, 8 and 9.
When RESET (pin 15) is taken HIGH, the chip will make output "0" go HIGH and remain HIGH.
When "Clock Inhibit" (pin 13) is taken HIGH, the counter will FREEZE on the output that is currently HIGH.
The clock signal must have a rise time faster than 5µsecs (V_{DD}=15v).





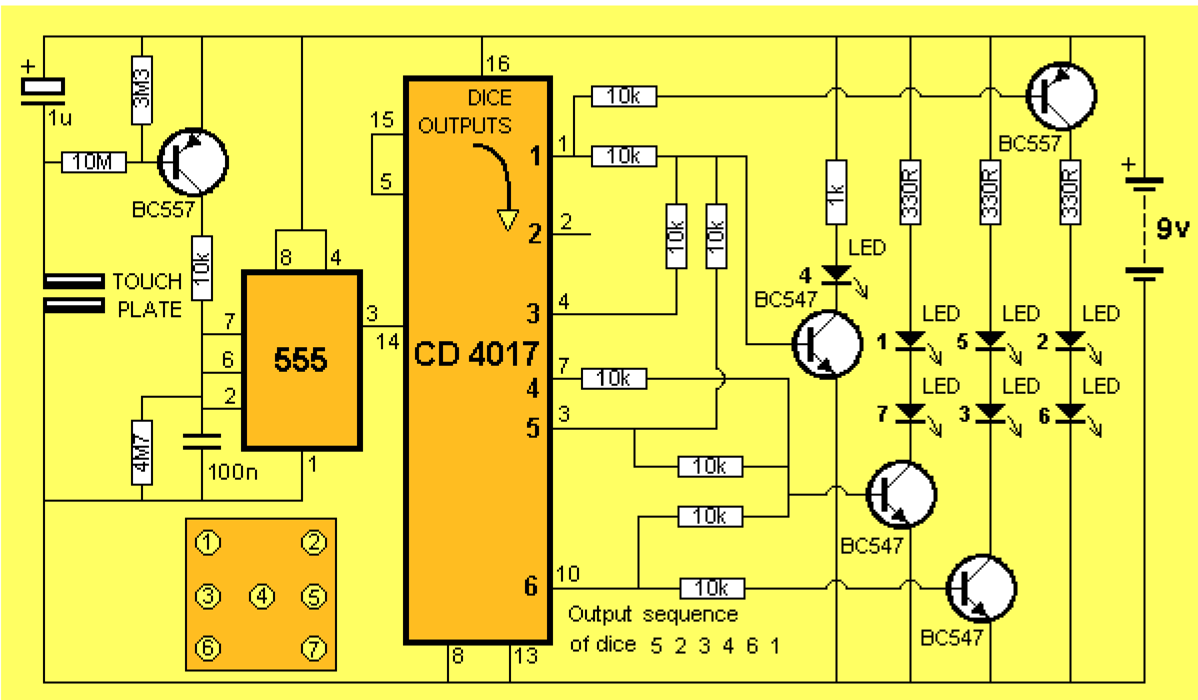
6 LEDs on the KITT SCANNER scan back and forth similar to the lights on the front of the KITT car in the movie.



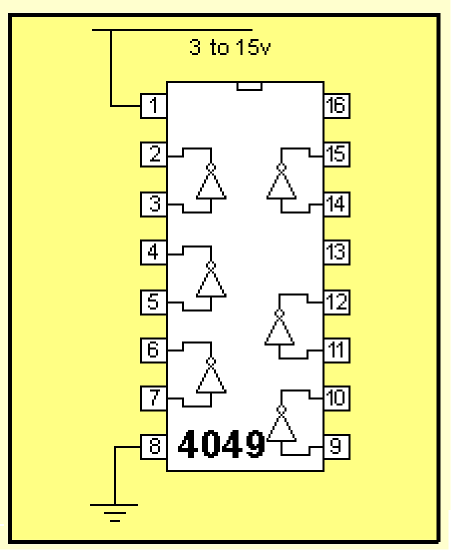


The 10 LEDs on the SCANNER turn on one-at-a-time, from left to right

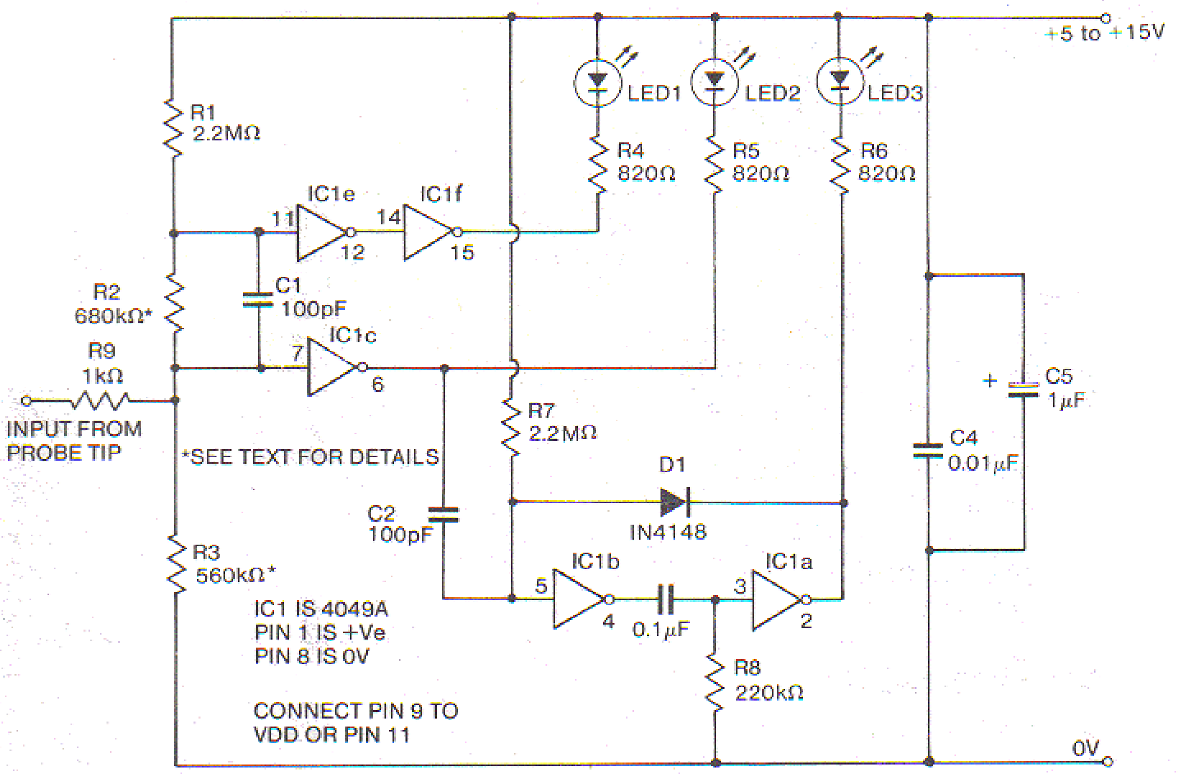
LED DICE



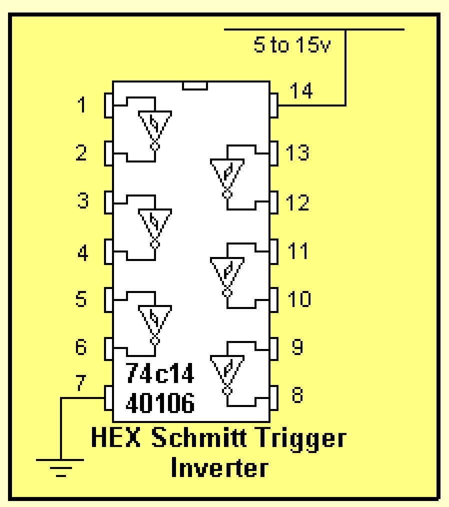
Logic Probe



The excellent input protection and wide supply voltage tolerance of the 4049 makes it ideal as the basis of a logic probe. The circuit below shows a logic probe for both CMOS and TTL circuits and will work over a 3-15v range and reliably up to 1.5MHz. On a 'low' input, $IC1_e$ will send IC1f low, lighting LED 1. On a high input $IC1_C$ will go 'low', lighting LED 2. $IC1_a$ and $IC1_b$ form a monostable circuit which 'stretches' short pulses to 15msec, so they can be seen. Thus on even high frequency pulse trains, LED 3 will flash.



40106 OR 74C14 HEX Schmitt Trigger IC



This chip is known by a number of identities. 74C14. It is also marketed as 40106, 40014, and 74HC14. These are all CMOS chips and are characterised by low current consumption, high input impedance and a supply voltage from 5v to 15v. **(Do not substitute 7414 or 74LS14. They are TTL chips and operate on 4.5v to 5.5v and have low impedance inputs.)**
The 74C14 contains 6 Schmitt Trigger gates.
Minimum supply voltage 5v
Maximum supply voltage 15v
Max current per output 10mA
Maximum speed of operation 4MHz
Current consumption approx 1uA with nothing connected to the inputs or outputs.

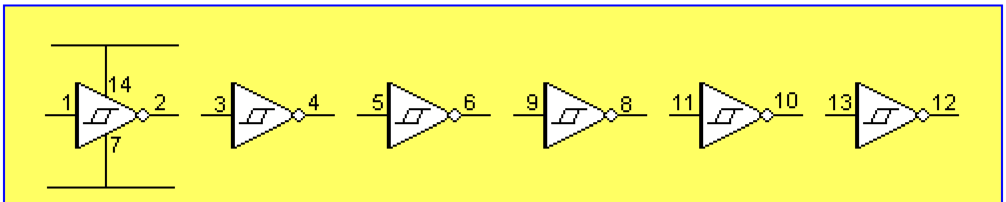
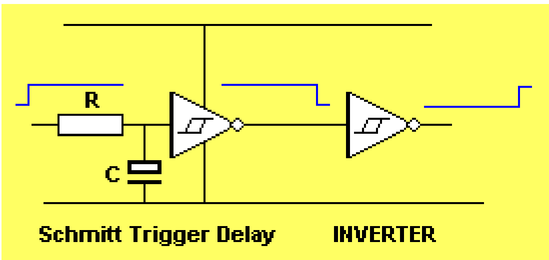


Fig: 8 The six Schmitt Trigger Gates for a 74c14 IC

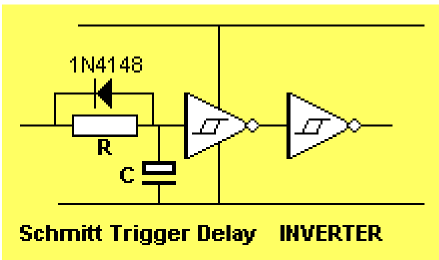
Here are some of the things you can do with the gates in the 40106 Hex Schmitt Trigger chip:

INVERTING

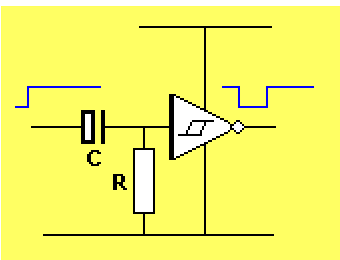
If the output is required to be the opposite of the circuit above, an inverter is added:



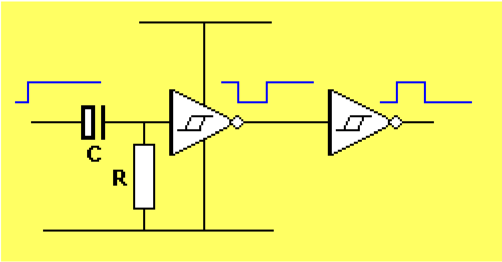
If a diode is added across the input resistor, the capacitor "C" will be discharged when the input goes low, so the "Delay Time" will be instantly available when the input goes HIGH:



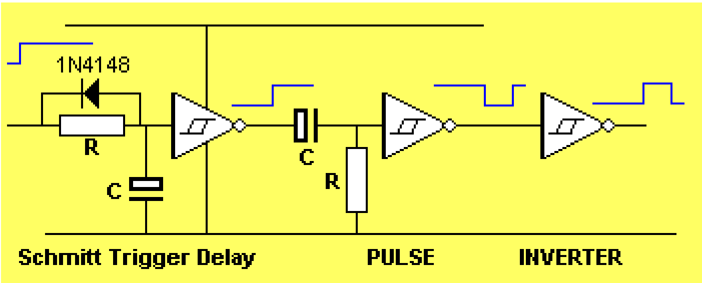
The following circuit produces a PULSE (a LOW pulse) when the input goes HIGH:



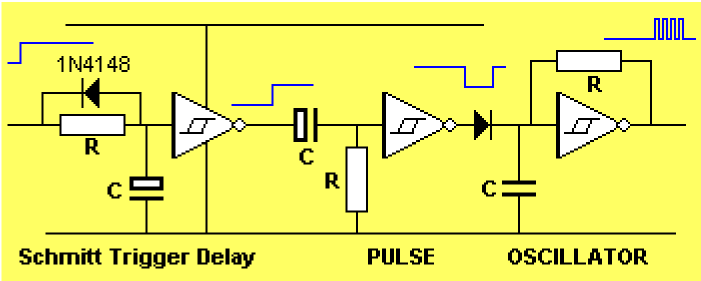
To invert the output, add an inverter:



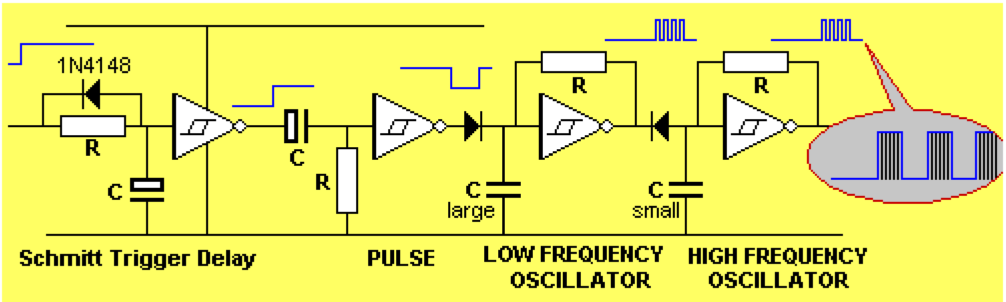
To produce a pulse after a delay, the following circuit can be used:



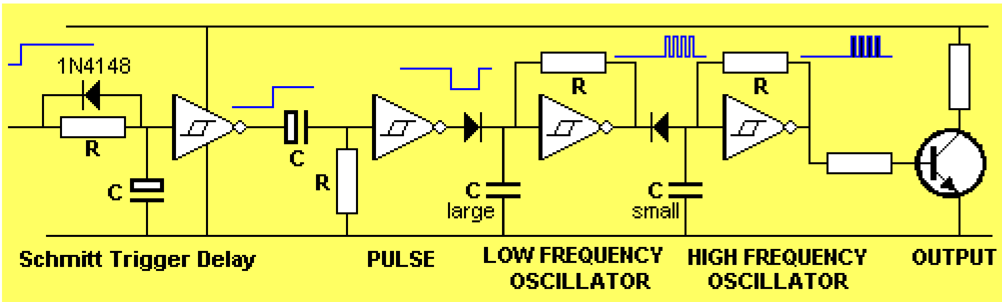
The following circuit produces a tone during the HIGH period. When the output of the second inverter is HIGH, it places a high on the input of the third inverter, via the diode. This is called "jamming" the oscillator and prevents the oscillator from operating. When the second inverter goes LOW, the oscillator will operate.



The oscillator above can be set to produce a 100Hz tone and this can activate a 2kHz oscillator to produce a 2-tone output. A "jamming diode" is needed between the third and fourth gates to allow the high-frequency oscillator to operate when the output of the low-frequency oscillator is HIGH.

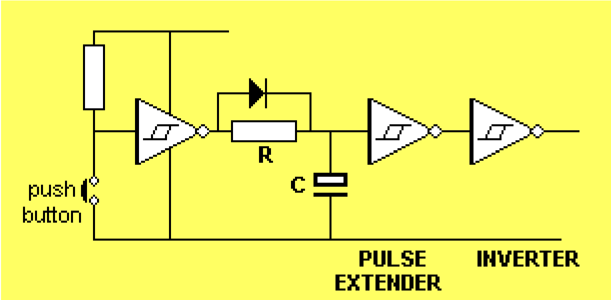


The output can be buffered with a transistor:

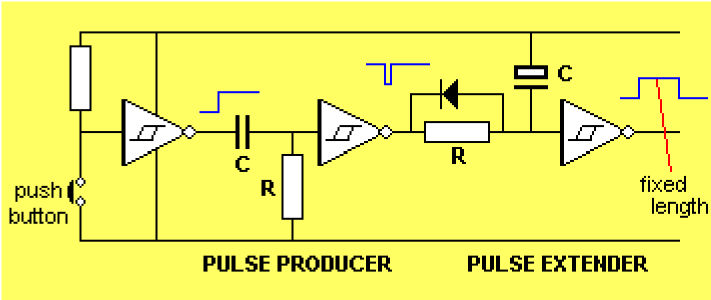


Extending the action of a push button

The action of a push button can be extended by adding the following circuit:

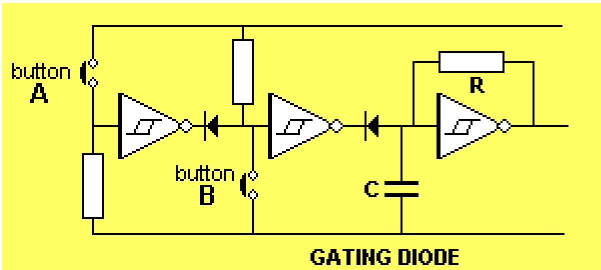


To produce a pulse of constant length, (no matter how long the button is pressed), the following circuit is needed:

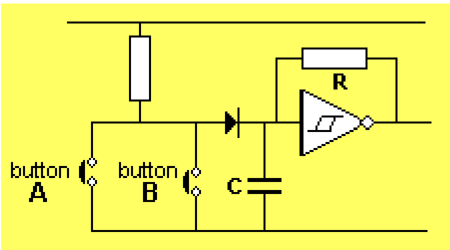


GATING

Gating is the action of preventing or allowing a signal to pass though a circuit.
In the following circuit, buttons "A" and "B" are gated to allow the oscillator to produce an output.
The first two inverters form an "OR-gate." When the output of the gate is HIGH it allows the oscillator to operate.

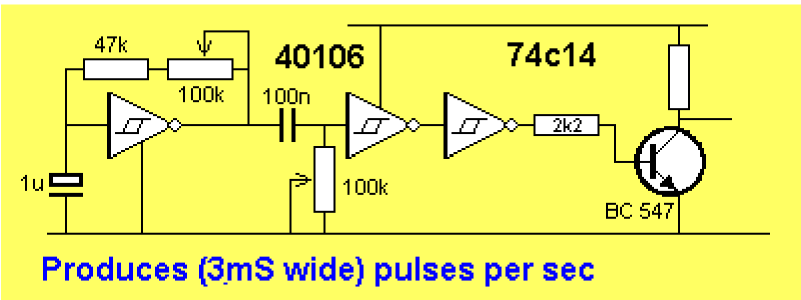


The second diode is called the **gating diode**. When the output of the second inverter is LOW, the capacitor is prevented from charging as the diode will not allow it to charge higher than 0.7v, and thus the oscillator does not operate.
When the output of the second inverter is HIGH, the capacitor is allowed to charge and discharge and thus oscillator will produce an output. If the push buttons can be placed together, the circuit can be simplified to:



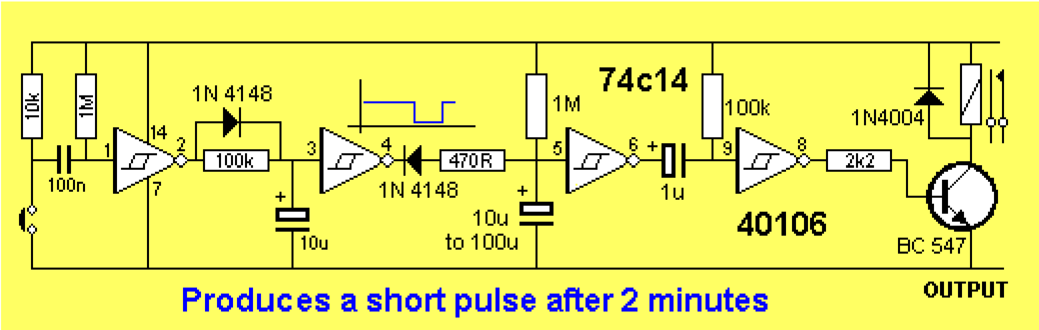
PULSER

The 74c14 can be used to produce a 3mS pulses every second. The circuit is adjustable to a wide range of requirements.



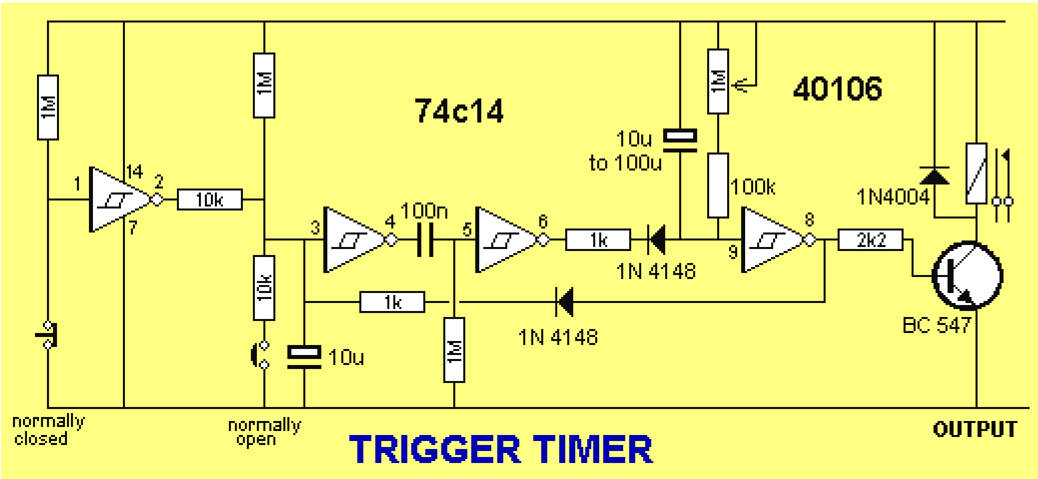
2 MINUTE TIMER

Some of the features we have discussed have been incorporated into the following circuit. The relay is energized for a short time, 2 minutes after the push-button is pressed. The push-button produces a brief LOW on pin 1, no matter how long it is pushed and this produces a pulse of constant length via the three components between pin 2 and 3.
This pulse is long enough to fully discharge the 100u timing electrolytic on pin 5.
The 100k and electrolytic between pins 6 and 9 are designed to produce a brief pulse to energize the relay.



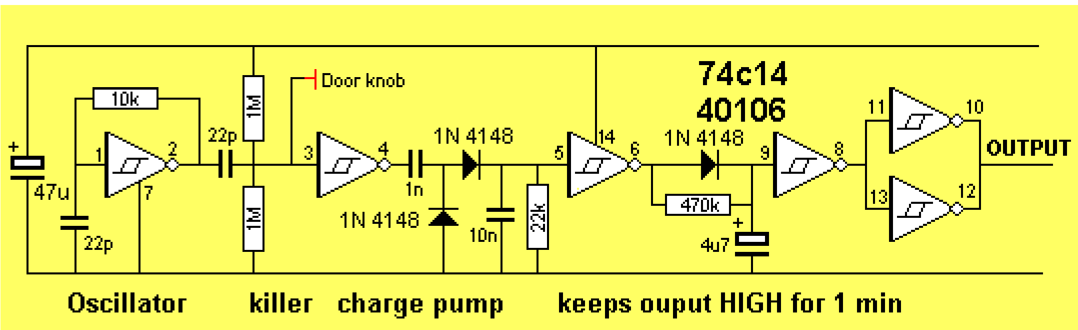
TRIGGER TIMER

The next design interfaces a "Normally Open" and "Normally Closed" switch to a delay circuit.
The feedback diode from the output prevents the inputs re-triggering the timer (during the delay period) so that a device such as a motor, globe or voice chip can be activated for a set period of time.

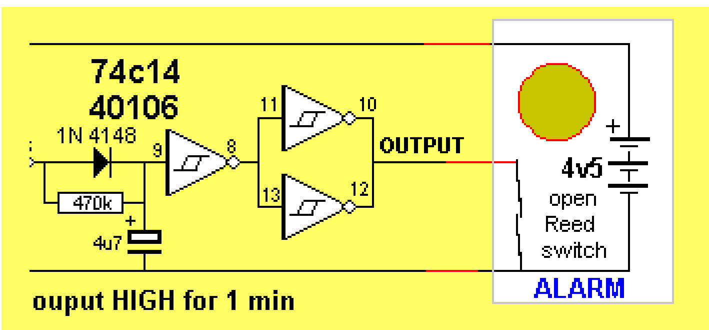


ALARM

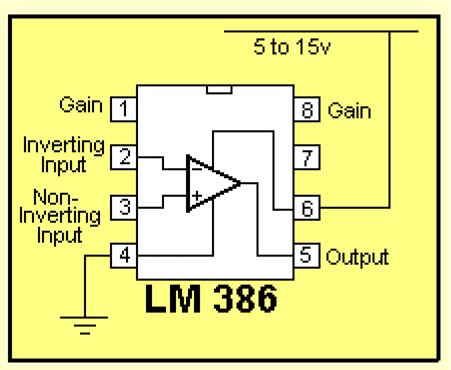
In the following circuit, the gates are used to detect the touch of a door knob and produce an output that goes HIGH for approx 1 minute.



The output of the above circuit can be taken to an alarm. Open the reed switch contacts and connect the reed switch to the output of the Door-knob alarm.

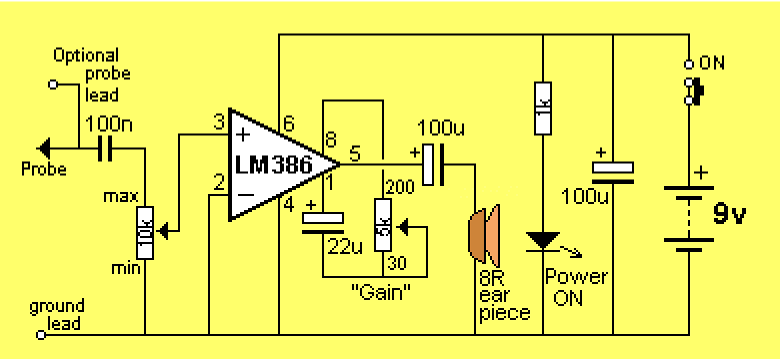


LM 386

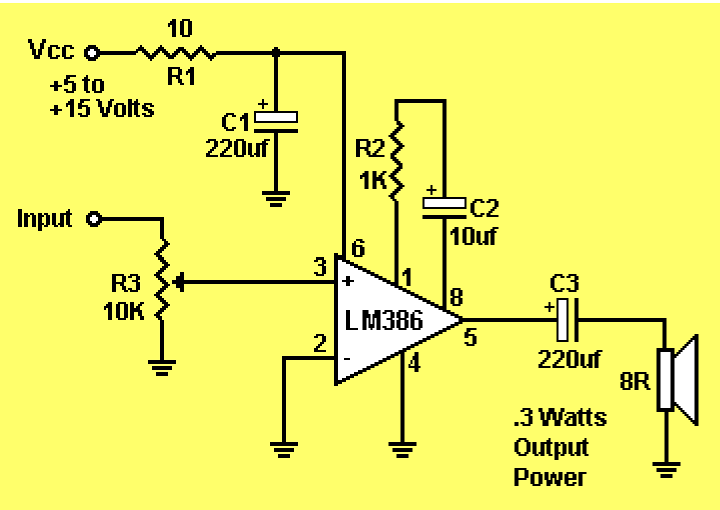


The LM 386 is an 8-pin Audio Power Amplifier
Minimum supply voltage 5v
Maximum supply voltage 15v

3 variations:
LM386-N1 cheapest variety 300mW
LM386-N3 500mW
LM386-N4 expensive variety 700mW



300mW amplifier using LM 386

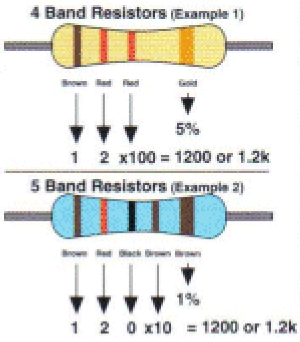


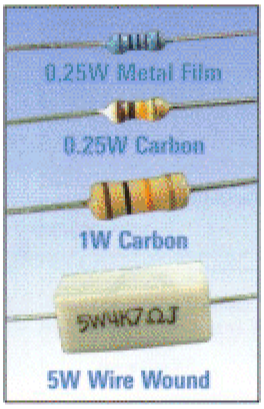
300mW amplifier using LM 386

Resistors

Reading Resistor Colour Codes

			Multiplier	Tolerance
Black	0	0	1	
Brown	1	1	10	1%
Red	2	2	100	2%
Orange	3	3	1,000	
Yellow	4	4	10,000	
Green	5	5	100,000	
Blue	6	6	1,000,000	
Violet	7	7		
Grey	8	8		
White	9	9		
Gold			0.1	5%
Silver			0.01	10%





A resistor will limit the current flow through itself to a calculable value based upon its resistance and the applied voltage (see Ohms Law). This means a resistor can be used to run a low voltage device from a higher voltage power supply by limiting the required power to a predetermined level. Resistors are not polarity sensitive.

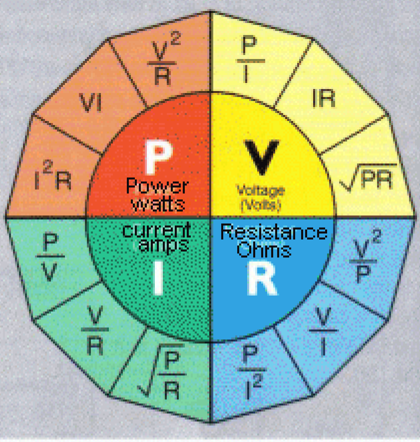
Tolerance The tolerance of a resistor refers to how close its actual resistance has to be to the value marked on it. Common tolerances are 5% and 1%.

Wattage Depending on the power requirements of a circuit, resistor wattage needs to be calculated to ensure that they don't over heat. The more common ratings available for resistors are 1/4 Watt, 1/2 Watt, 1 Watt & 5 Watt. The wattage required for different circuits can be calculated by using the power formula described later.

Values Because it would be impractical to carry every possible value of resistor, they are available in pre-selected ranges. These ranges are known as preferred values. The E 12 series, which is the most common series, (12 Values per 100) is denoted as: 10Ω, 12Ω, 15Ω, 18Ω, 22Ω, 27Ω, 33Ω, 39Ω, 47Ω, 56Ω, 68Ω, 82Ω.
This does not limit the range of resistors to a total of twelve values, but each resistor value must begin with a number from the series and be a multiple of x0.1, x1, x10, x100, x1000, x10000 etc. i.e. 1.5Ω, 15Ω, 150Ω, 1500Ω, 15,000Ω.

The E 24 series has 24 values per 100 which includes the above sequence plus these extra values: 11Ω, 13Ω, 16Ω, 20Ω, 24Ω, 30Ω, 36Ω, 43Ω, 51Ω, 62Ω, 75Ω, 91Ω.

Formula Wheel



Using this formula wheel it is possible to calculate power, volts, amps or resistance for a given problem. ie. if you have two of the variables, for example power and volts, it is possible to find the amps in a circuit.

This wheel expresses volts as V, however, if you are studying old text books, you may see volts shown as E.

Resistors

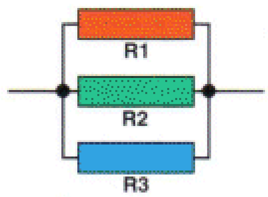
Resistors in Series

When two or more resistors are placed in series, (in line with each other), the overall resistance of the resistor network will change. The new value can be calculated from:-

$$R_{Total} = R1 + R2 + R3 + etc...$$

Resistors in Parallel

Calculating resistors in parallel is a little more complicated than resistors in series.



$$R_{Total} = \frac{1}{\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{etc .....}\right)}$$

Power (Watts)

Power (Watts)	=	Current (Amps)	x	Voltage (Volts)
P	=	I	x	V

Where: V = Volts, I = Amps

P = Power

This formula is used in many situations, from calculating the wattage of a resistor, to working out if an appliance will overload a particular power source. A useful variation of this formula is :-

$P = I^2 \times R$

Ohms Law

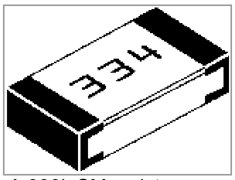
Ohms law is undoubtedly the most commonly used formula in electronics today. It defines the relationship between voltage, current and resistance. Its uses vary from calculating the value of a resistor to protect a LED (Light Emitting Diode) from destruction when run on a higher voltage supply than recommended, to calculating the current that a heater element will draw.

Voltage (Volts)	=	Current (Amps)	x	Resistance (Ohms)
V	=	I	x	R

Where: V = Volts, I = Amps, R = Resistance

Surface Mount Resistors

All SM resistors conform to a 3-digit or 4-digit code. But there are a number of codes, according to the tolerance of the resistor. It's getting very complicated.
Here is a basic 3-digit SM resistor:



A 330k SM resistor

The first two digits represent the two digits in the answer. The third digit represents the number of zero's you must place after the two digits. The answer will be OHMS. For example: 334 is written 33 0 000. This is written 330,000 ohms. The comma can be replaced by the letter "k". The final answer is: 330k.
222 = 22 00 = 2,200 = 2k2
473 = 47 000 = 47,000 = 47k
105 = 10 00000 = 1,000,000 = 1M = one million ohms
There is one trick you have to remember. Resistances less than 100 ohms are written: 100, 220, 470. These are 10 and NO zero's = 10 ohms = 10R
or 22 and no zero's = 22R or 47 and no zero's = 47R. Sometimes the resistor is marked: 10, 22 and 47 to prevent a mistake.
Remember:
R = ohms k = kilo ohms = 1,000 ohms M = Meg = 1,000,000 ohms
The 3 letters (R, k and M) are put in place of the decimal point. This way you cannot make a mistake when reading a value of resistance.

THE COMPLETE RANGE OF SM RESISTOR MARKINGS:

0R1 = 0.1ohm	470 = 47R	332 = 3k3	224 = 220k
R22 = 0.22ohm	560 = 56R	392 = 3k9	274 = 270k
R33 = 0.33ohm	680 = 68R	472 = 4k7	334 = 330k
R47 = 0.47ohm	820 = 82R	562 = 5k6	394 = 390k
R68 = 0.68ohm	101 = 100R	682 = 6k8	474 = 470k
R82 = 0.82ohm	121 = 120R	822 = 8k2	564 = 560k
1R0 = 1R	151 = 150R	103 = 10k	684 = 680k
1R2 = 1R2	181 = 180R	123 = 12k	824 = 820k
2R2 = 2R2	221 = 220R	153 = 15k	105 = 1M0
3R3 = 3R3	271 = 270R	183 = 18k	125 = 1M2
4R7 = 4R7	331 = 330R	223 = 22k	155 = 1M5
5R6 = 5R6	391 = 390R	273 = 27k	185 = 1M8
6R8 = 6R8	471 = 470R	333 = 33k	225 = 2M2
8R2 = 8R2	561 = 560R	393 = 39k	275 = 2M7
100 = 10R	681 = 680R	473 = 47k	335 = 3M3
120 = 12R	821 = 820R	563 = 56k	395 = 3M9
150 = 15R	102 = 1k0	683 = 68k	475 = 4M7
180 = 18R	122 = 1k2	823 = 82k	565 = 5M6
220 = 22R	152 = 1k5	104 = 100k	685 = 6M8
270 = 27R	182 = 1k8	124 = 120k	825 = 8M2
330 = 33R	222 = 2k2	154 = 150k	106 = 10M0
390 = 39R	272 = 2k7	184 = 180k	

The complete range of SM resistor markings for 4-digit code:

0000 =00R	10R0 = 10R	1000 = 100R	1001 = 1k0	1002 = 10k	1003 = 100k	1004 = 1M
00R1 = 0.1ohm	11R0 = 11R	1100 = 110R	1101 = 1k1	1102 = 11k	1103 = 110k	1104 = 1M1
0R22 = 0.22ohm	12R0 = 12R	1200 = 120R	1201 = 1k2	1202 = 12k	1203 = 120k	1204 = 1M2
0R47 = 0.47ohm	13R0 = 13R	1300 = 130R	1301 = 1k3	1302 = 13k	1303 = 130k	1304 = 1M3
0R68 = 0.68ohm	15R0 = 15R	1500 = 150R	1501 = 1k5	1502 = 15k	1503 = 150k	1504 = 1M5
0R82 = 0.68ohm	16R0 = 16R	1600 = 160R	1601 = 1k6	1602 = 16k	1603 = 160k	1604 = 1M6
1R00 = 1ohm	18R0 = 18R	1800 = 180R	1801 = 1k8	1802 = 18k	1803 = 180k	1804 = 1M8
1R20 = 1R2	20R0 = 20R	2000 = 200R	2001 = 2k0	2002 = 20k	2003 = 200k	2004 = 2M0
2R20 = 2R2	22R0 = 22R	2200 = 220R	2201 = 2k2	2202 = 22k	2203 = 220k	2204 = 2M2
3R30 = 3R3	24R0 = 24R	2400 = 240R	2401 = 2k4	2402 = 24k	2403 = 240k	2404 = 2M4
6R80 = 6R8	27R0 = 27R	2700 = 270R	2701 = 2k7	2702 = 27k	2703 = 270k	2704 = 2M7
8R20 = 8R2	30R0 = 30R	3000 = 300R	3001 = 3k0	3002 = 30k	3003 = 300k	3004 = 3M0
	33R0 = 33R	3300 = 330R	3301 = 3k3	3302 = 33k	3303 = 330k	3304 = 3M3
	36R0 = 36R	3600 = 360R	3601 = 3k6	3602 = 36k	3603 = 360k	3604 = 3M6
	39R0 = 39R	3900 = 390R	3901 = 3k9	3902 = 39k	3903 = 390k	3904 = 3M9
	43R0 = 43R	4300 = 430R	4301 = 4k3	4302 = 43k	4303 = 430k	4304 = 4M3
	47R0 = 47R	4700 = 470R	4701 = 4k7	4702 = 47k	4703 = 470k	4704 = 4M7
	51R0 = 51R	5100 = 510R	5101 = 5k1	5102 = 51k	5103 = 510k	5104 = 5M1
	56R0 = 56R	5600 = 560R	5601 = 5k6	5602 = 56k	5603 = 560k	5604 = 5M6
	62R0 = 62R	6200 = 620R	6201 = 6k2	6202 = 62k	6303 = 620k	6204 = 6M2
	68R0 = 68R	6800 = 680R	6801 = 6k8	6802 = 68k	6803 = 680k	6804 = 6M8
	75R0 = 75R	7500 = 750R	7501 = 7k5	7502 = 75k	7503 = 750k	7504 = 7M5
	82R0 = 82R	8200 = 820R	8201 = 8k2	8202 = 82k	8203 = 820k	8204 = 8M2
	91R0 = 91R	9100 = 910R	9101 = 9k1	9102 = 91k	9103 = 910k	9104 = 9M1
						1005 = 10M

0000 is a value on a surface-mount resistor. It is a zero-ohm **LINK**!
Resistances less than 10 ohms have 'R' to indicate the position of the decimal point. Here are some examples:

Three Digit Examples	Four Digit Examples
330 is 33 ohms *- not 330 ohms*	**1000 is 100 ohms** *- not 1000 ohms*
221 is 220 ohms	**4992 is 49 900 ohms, or 49k9**
683 is 68 000 ohms, or 68k	**1623 is 162 000 ohms, or 162k**
105 is 1 000 000 ohms, or 1M	**0R56 or R56 is 0.56 ohms**
8R2 is 8.2 ohms	

A new coding system has appeared on **1% types**. This is known as the EIA-96 marking method. It consists of a three-character code. The first two digits signify the 3 significant digits of the resistor value, using the lookup table below. The third character - a letter - signifies the multiplier.

code	value	code	value	code	value	code	value	code	value	code	value
01	100	17	147	33	215	49	316	65	464	81	681
02	102	18	150	34	221	50	324	66	475	82	698
03	105	19	154	35	226	51	332	67	487	83	715
04	107	20	158	36	232	52	340	68	499	84	732
05	110	21	162	37	237	53	348	69	511	85	750
06	113	22	165	38	243	54	357	70	523	86	768
07	115	23	169	39	249	55	365	71	536	87	787
08	118	24	174	40	255	56	374	72	549	88	806
09	121	25	178	41	261	57	383	73	562	89	825
10	124	26	182	42	237	58	392	74	576	90	845
11	127	27	187	43	274	59	402	75	590	91	866
12	130	28	191	44	280	60	412	76	604	92	887
13	133	29	196	45	287	61	422	77	619	93	909
14	137	30	200	46	294	62	432	78	634	94	931
15	140	31	205	47	301	63	442	79	649	95	953
16	143	32	210	48	309	64	453	80	665	96	976

The **multiplier** letters are as follows:

letter	mult		letter	mult
F	100000		B	10
E	10000		A	1
D	1000		X or S	0.1
C	100		Y or R	0.01

22A is a 165 ohm resistor, **68C** is a 49900 ohm (49k9) and **43E** a 2740000 (2M74). This marking scheme applies to 1% resistors only.

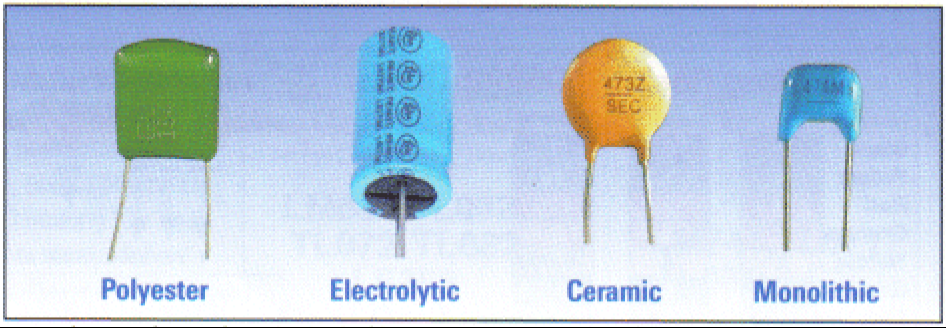
A similar arrangement can be used for **2% and 5%** tolerance types. The multiplier letters are identical to 1% ones, but occur **before** the number code and the following **code** is used:

2%					5%				
code	value		code	value	code	value		code	value
01	100		13	330	25	100		37	330
02	110		14	360	26	110		38	360
03	120		15	390	27	120		39	390
04	130		16	430	28	130		40	430
05	150		17	470	29	150		41	470
06	160		18	510	30	160		42	510
07	180		19	560	31	180		43	560
08	200		20	620	32	200		44	620
09	220		21	680	33	220		45	680
10	240		22	750	34	240		46	750
11	270		23	820	35	270		47	820
12	300		24	910	36	300		48	910

With this arrangement, **C31** is 5%, 18000 ohm (18k), and **D18** is 510000 ohms (510k) 2% tolerance.
Always check with an ohm-meter (a multimeter) to make sure.

Chip resistors come in the following styles and ratings:
Style: 0402, 0603, 0805, 1206, 1210, 2010, 2512, 3616, 4022
Power Rating: 0402(1/16W), 0603(1/10W), 0805(1/8W), 1206(1/4W), 1210(1/3W), 2010(3/4W), 2512(1W), 3616(2W), 4022(3W)
Tolerance: 0.1%, 0.5%, 1%, 5%
Temperature Coefficient: 25ppm 50ppm 100ppm

CAPACITOR DATA



A capacitor works on the principle of having two conductive plates which are very close and are parallel to each other. When a charge is applied to one plate of the capacitor, the electrons will generate an approximately equal, but opposite charge on the other plate. Capacitors will pass AC current, but will block DC current. A capacitor can also he used to smooth voltage ripple, as in DC power supplies. Capacitance is measured in Farads (F).

Capacitor Parameters

Capacitors have five parameters:
Capacitance (Farads),
Tolerance (%),
Maximum Working Voltage (Volts)
Surge Voltage (Volts) and leakage

Because a Farad is a very large unit, most capacitors are normally measured in the ranges of pico, nano and micro farads.

Working Voltage
This refers to the maximum voltage that should be placed across the capacitor under normal operating conditions.

Surge Voltage
The maximum instantaneous voltage a capacitor can withstand. If the surge voltage is exceeded over too long a period there is a very good chance that the capacitor will be destroyed by the voltage punching through the insulating material inside the casing of the capacitor. If a circuit has a surging characteristic, choose a capacitor with a high rated surge voltage.

Leakage
Refers to the amount of charge that is lost when the capacitor has a voltage across its terminals. If a capacitor has a low leakage it means very little power is lost. Generally leakage is very small and is not normally a consideration for general purpose circuits.

Tolerance
As with resistors, tolerance indicates how close the capacitor is to its noted value. These are normally written on the larger capacitors and encoded on the small ones.

Code	Tolerance	Code	Tolerance
C	**±.25pF**	**D**	**±0.5pF**
E	**±1pF**	**G**	**±2%**
J	**±5%**	**K**	**±10%**
L	**±15%**	**M**	**±20%**
N	**±30%**	**Z**	**+80-20%**

Capacitor Markings
There are two methods for marking capacitor values. One is to write the information numerically directly onto the capacitor itself. The second is to use the EIA coding system.

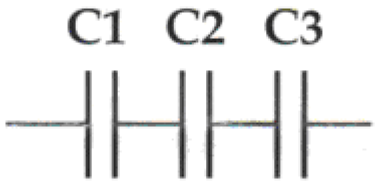
EIA Coding
The EIA code works on a very similar principle to the resistor colour code. The first two digits refer to the value with the third being the multiplier. The fourth character represents the tolerance.
When the EIA code is used, the value will always be in Pico-Farads (see Decimal Multipliers).

Example 103K
This expands to:
1 = 1
0 = 0
3 = x 1,000
K = 10% (sec Capacitor Tolerance for listings)
Then we combine these numbers together:
1 0 x 1 000 = 10 000pF = 0.01μF, = 10n ±10% tolerance

Example 335K
This expands to:
3 = 3
3 = 3
E = x100,000
K = ±10%
Then we combine these numbers together
3 3 x100,000 = 3,300,000pF = 3,300nF = 3.3uF 10% tolerance.

Capacitors in Series

Capacitors in series can be calculated by:

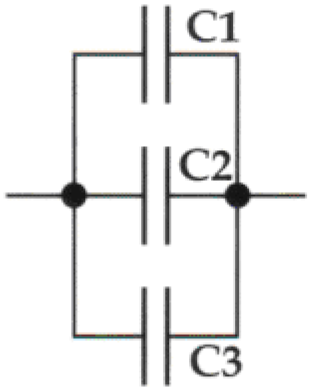


$$C_{Total} = \frac{1}{\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \text{etc .....}\right)}$$

Note:- The new value will always be lower.

Capacitors in Parallel

When capacitors are placed in parallel they can be simply added together.



$$C_{Total} = C1 + C2 + C3 + \text{etc....}$$

Note :- The new capacitance value will be higher.

Potentiometers

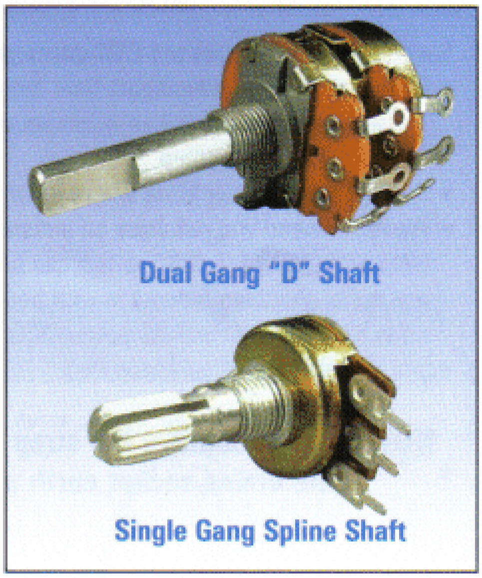
Potentiometers (usually called pots) are essentially a variable resistor. There are two common types of potentiometers. These are linear and logarithmic types. These relate to the change in resistance with respect to rotation of the potentiometer shaft. Logarithmic pots are commonly used in volume control applications.

Linear pots are commonly marked with a "B" prefix, and log pots with an "A" prefix.

For example

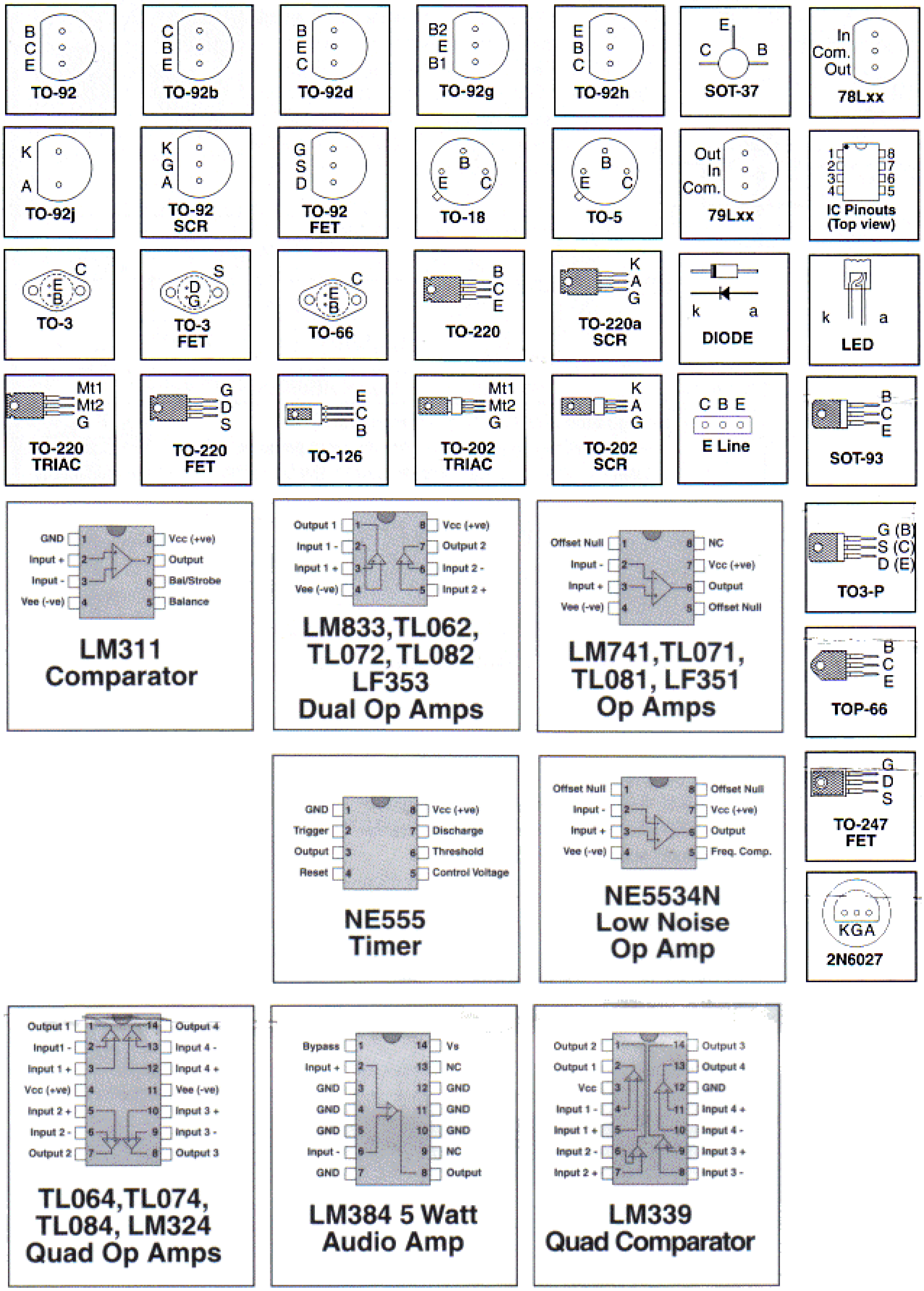
B100K = 100 k ohms - linear

A20K = 20 k ohms - logarithmic



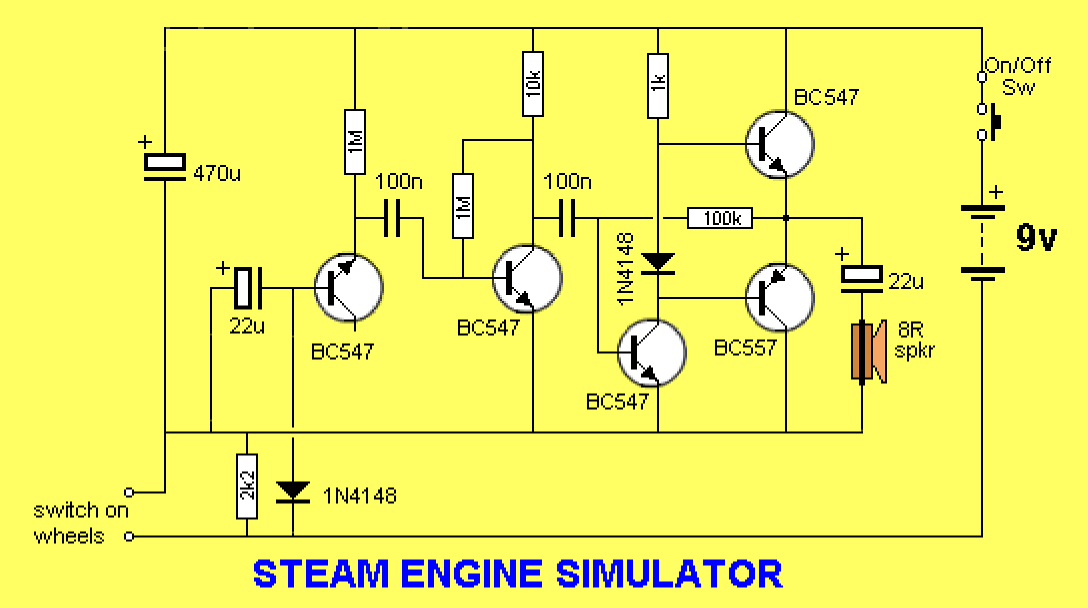
Dual Gang "D" Shaft

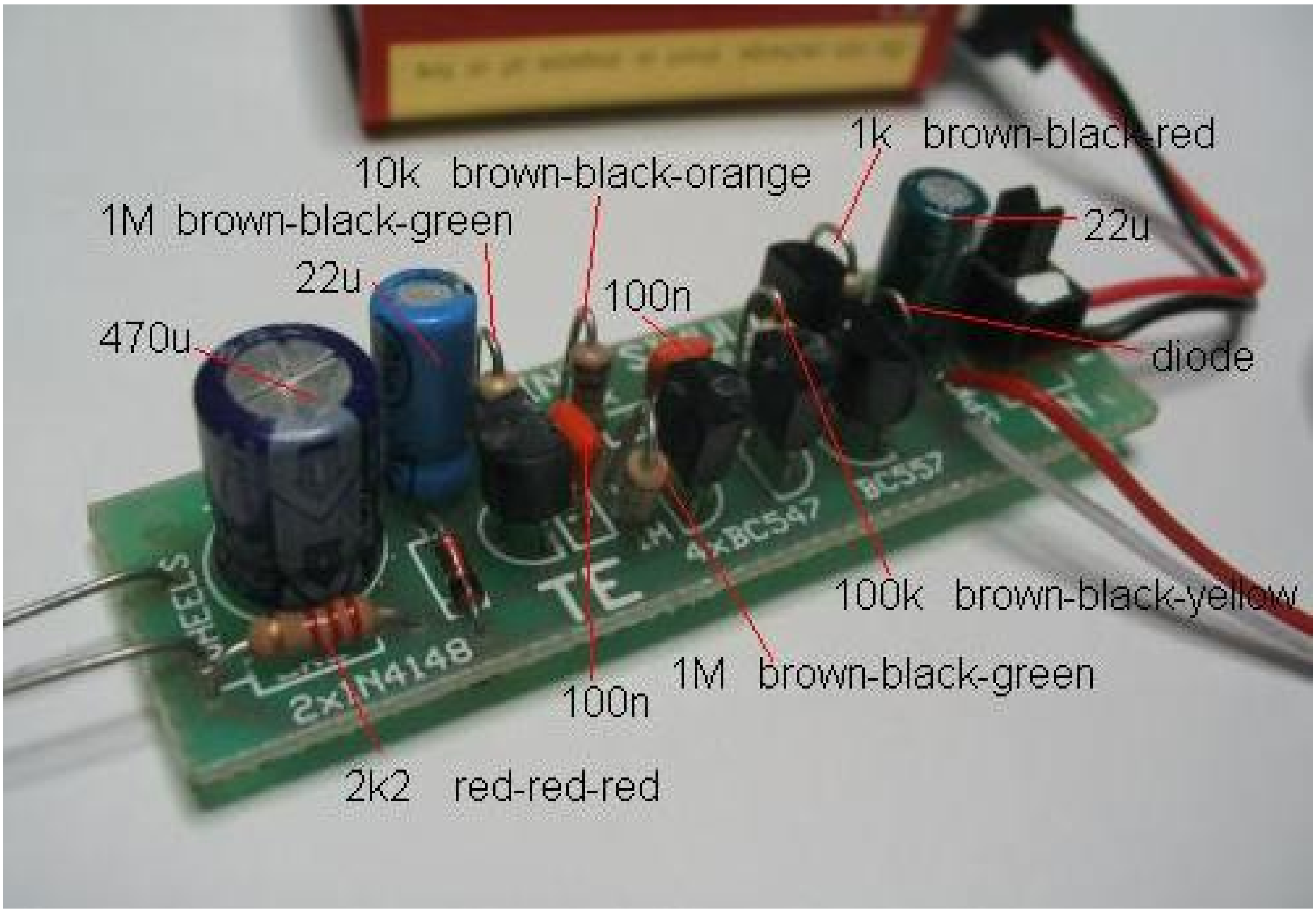
Single Gang Spline Shaft



B C E TO-92
C B E TO-92b
B E C TO-92d
B2 E B1 TO-92g
E B C TO-92h
E C B SOT-37
In Com. Out 78Lxx
K A TO-92j
K G A TO-92 SCR
G S D TO-92 FET
B E C TO-18
B E C TO-5
Out In Com. 79Lxx
1 2 3 4 8 7 6 5 IC Pinouts (Top view)
C E B TO-3
S D G TO-3 FET
C E B TO-66
B C E TO-220
K A G TO-220a SCR
k a DIODE
k a LED
Mt1 Mt2 G TO-220 TRIAC
G D S TO-220 FET
E C B TO-126
Mt1 Mt2 G TO-202 TRIAC
K A G TO-202 SCR
C B E E Line
B C E SOT-93
GND 1, Input + 2, Input - 3, Vee (-ve) 4, Balance 5, Bal/Strobe 6, Output 7, Vcc (+ve) 8
LM311 Comparator
Output 1 1, Input 1 - 2, Input 1 + 3, Vee (-ve) 4, Input 2 + 5, Input 2 - 6, Output 2 7, Vcc (+ve) 8
LM833,TL062, TL072, TL082 LF353 Dual Op Amps
Offset Null 1, Input - 2, Input + 3, Vee (-ve) 4, Offset Null 5, Output 6, Vcc (+ve) 7, NC 8
LM741,TL071, TL081, LF351 Op Amps
G (B) S (C) D (E) TO3-P
B C E TOP-66
GND 1, Trigger 2, Output 3, Reset 4, Control Voltage 5, Threshold 6, Discharge 7, Vcc (+ve) 8
NE555 Timer
Offset Null 1, Input - 2, Input + 3, Vee (-ve) 4, Freq. Comp. 5, Output 6, Vcc (+ve) 7, Offset Null 8
NE5534N Low Noise Op Amp
G D S TO-247 FET
KGA 2N6027
Output 1 1, Input1 - 2, Input 1 + 3, Vcc (+ve) 4, Input 2 + 5, Input 2 - 6, Output 2 7, Output 3 8, Input 3 - 9, Input 3 + 10, Vee (-ve) 11, Input 4 + 12, Input 4 - 13, Output 4 14
TL064,TL074, TL084, LM324 Quad Op Amps
Bypass 1, Input + 2, GND 3, GND 4, GND 5, Input - 6, GND 7, Output 8, NC 9, GND 10, GND 11, GND 12, NC 13, Vs 14
LM384 5 Watt Audio Amp
Output 2 1, Output 1 2, Vcc 3, Input 1 - 4, Input 1 + 5, Input 2 - 6, Input 2 + 7, Input 3 - 8, Input 3 + 9, Input 4 - 10, Input 4 + 11, GND 12, Output 4 13, Output 3 14
LM339 Quad Comparator

STEAM SIMULATOR





A realistic steam sound can be generated with a 4-transistor directly-coupled amplifier connected to a small speaker. The “white noise” is generated by the breakdown across the junction of a transistor and it is activated by a switch made up of contacts touching the wheel of one of the carriages. As the train speeds up and slows down, the sound corresponds to the movement. See Talking Electronics website for the full project.

27MHz LINKS

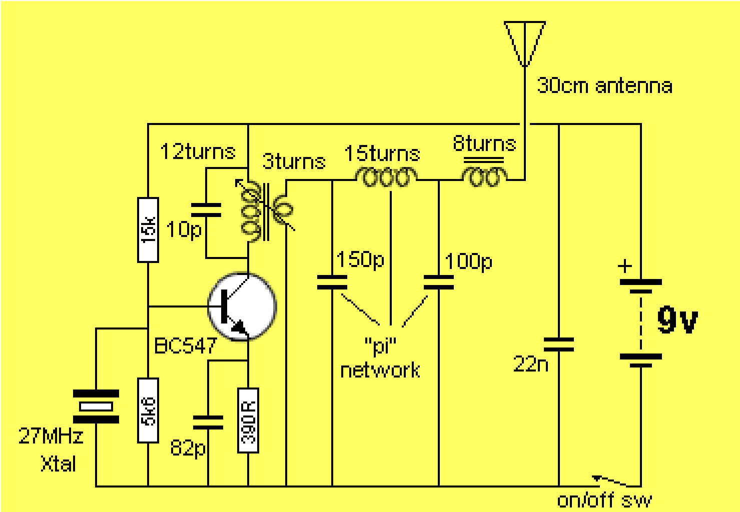


Fig 1. The 27MHz Transmitter

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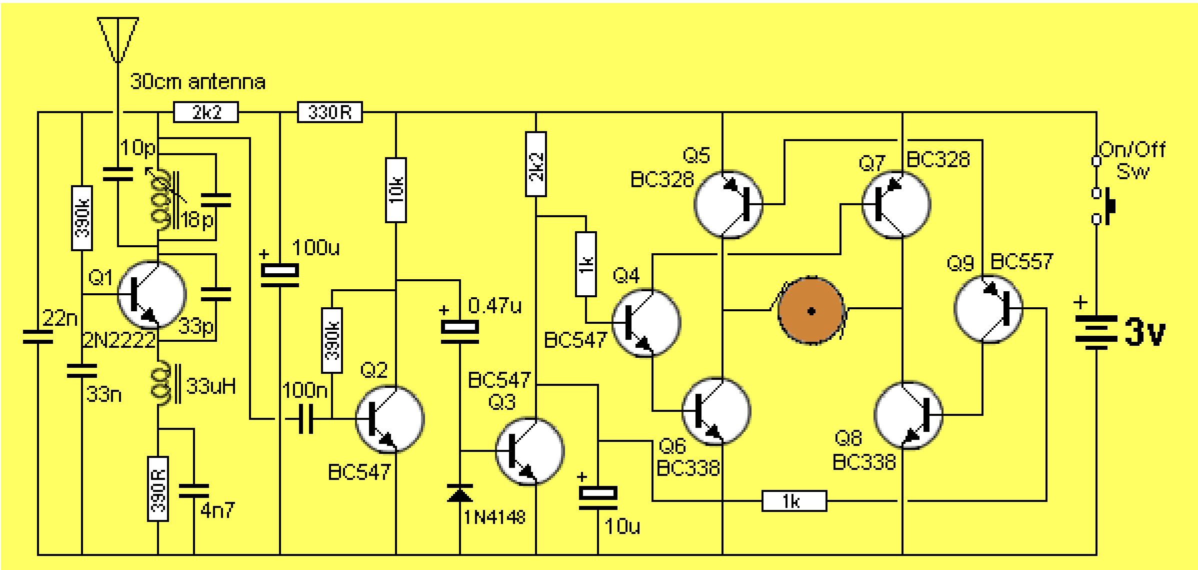
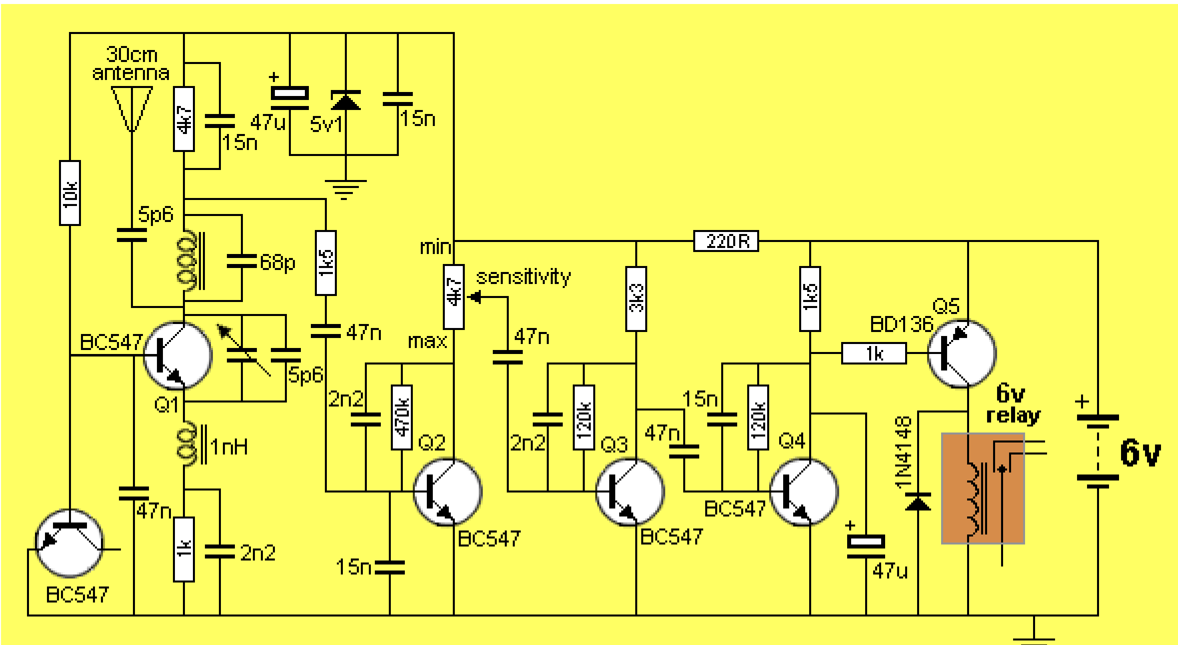


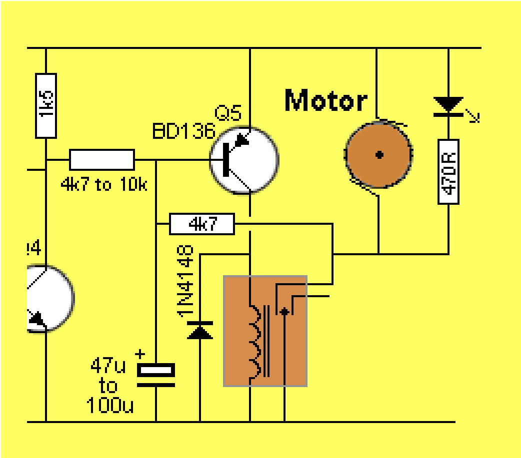
Fig 2. The 27MHz Receiver

Here is the circuit from a 27MHz remote control car. It is a simple single-channel link that activates the car in the forward direction when no carrier is being received, and the motor reverses when a carrier is detected. See Talking Electronics website for more details - **27MHz Links**.

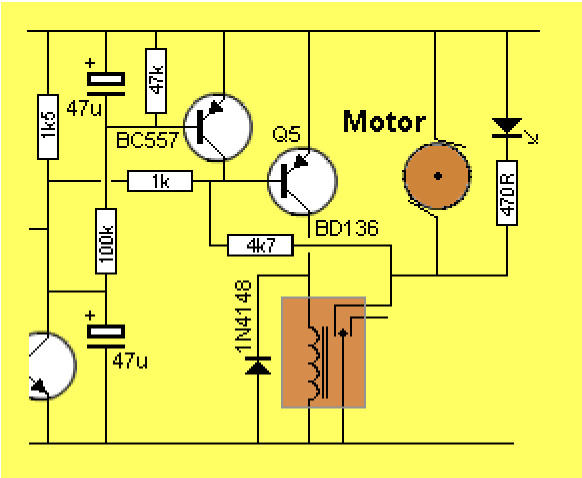


27MHz Receiver

This is a single channel receiver, similar to the circuit above.
It can be modified to turn on a "latch" a relay. This means the relay can be turned on remotely but it cannot be turned off. The second circuit shows the modification to turn the relay ON with a short tone and OFF with a long tone.

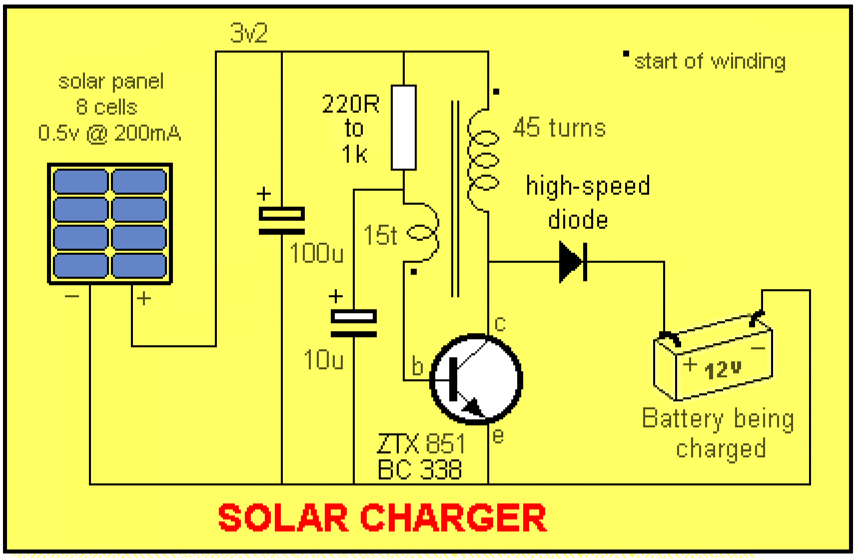


The relay can be turned on but not turned off



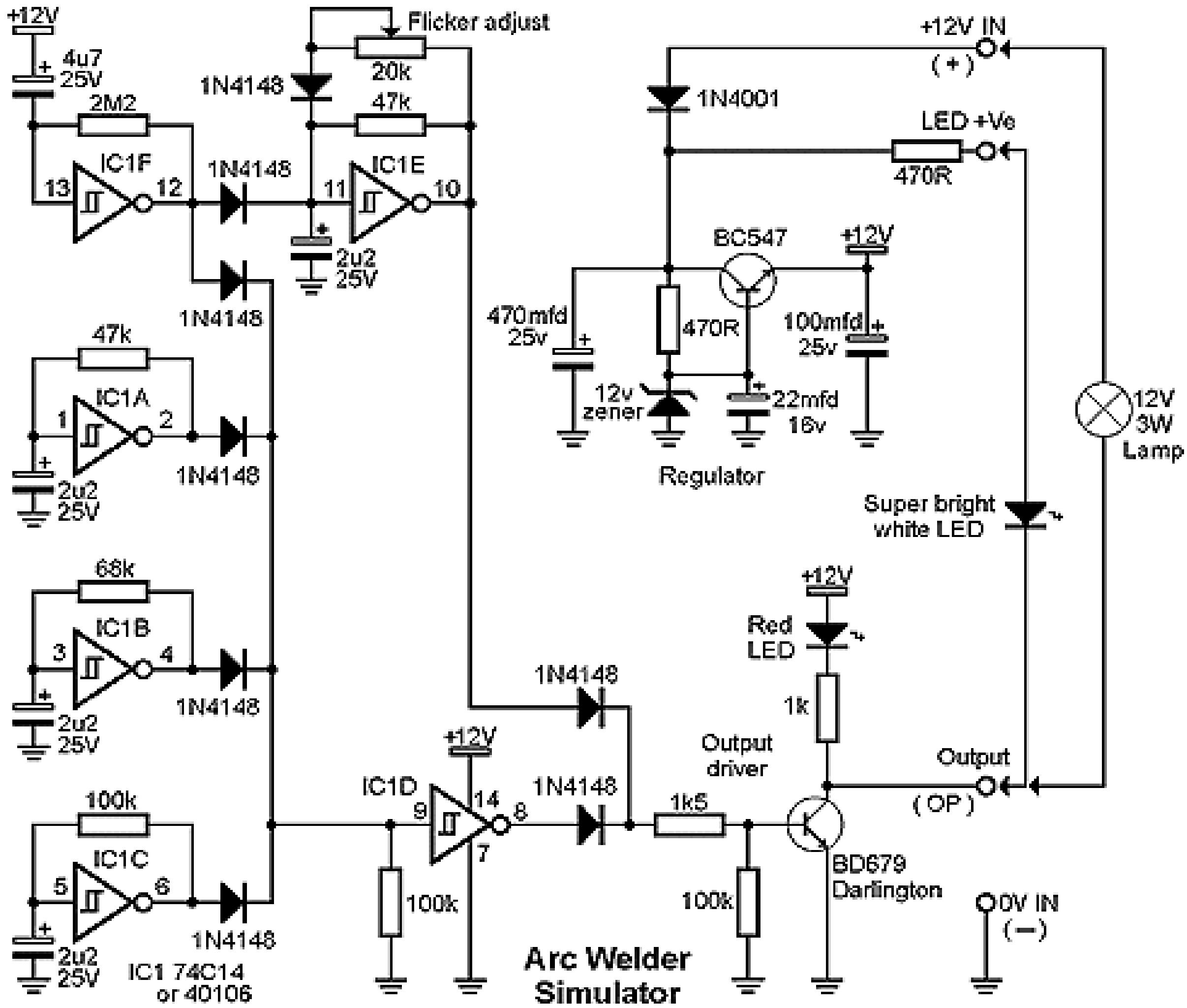
The relay can be turned on with a short tone and turned off with a long tone

SOLAR CHARGER



This solar charger can be used to charge a 12v battery from any number of solar cells. The circuit automatically adjusts for any input voltage and any output voltage. See Talking Electronics website for the full project.

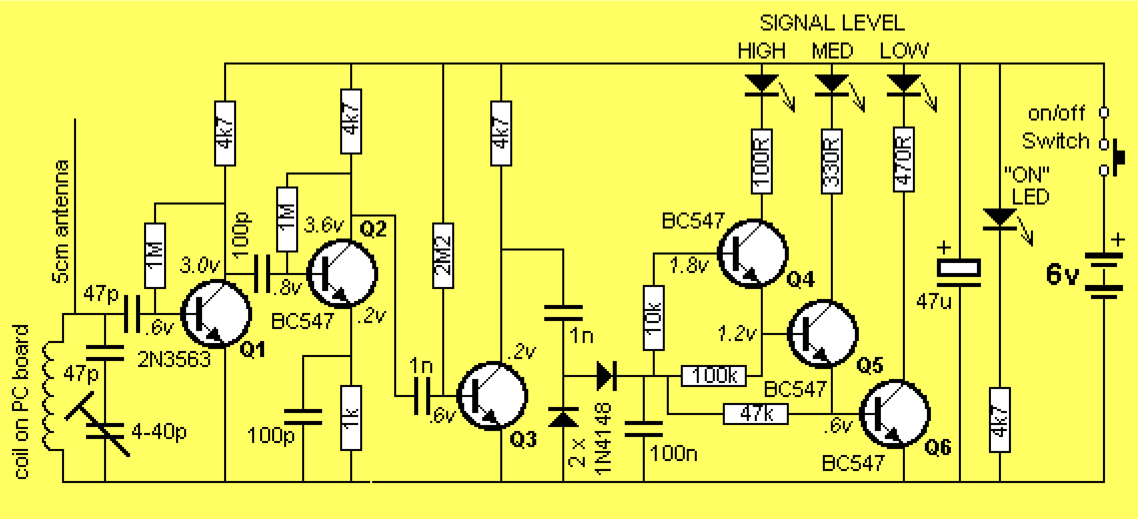
ARC WELDER



+12V
4u7
25V
2M2
IC1F
13
12
1N4148
Flicker adjust
20k
47k
IC1E
11
10
2u2
25V
47k
IC1A
1
2
68k
IC1B
3
4
100k
IC1C
5
6
IC1 74C14
or 40106
IC1D
9
14
8
7
100k
+12V IN
(+)
1N4001
LED +Ve
470R
BC547
470mfd
25v
12v
zener
22mfd
16v
100mfd
25v
Regulator
12V
3W
Lamp
Super bright
white LED
Red
LED
1k
Output
driver
1k5
Output
(OP)
BD679
Darlington
0V IN
(−)
Arc Welder
Simulator

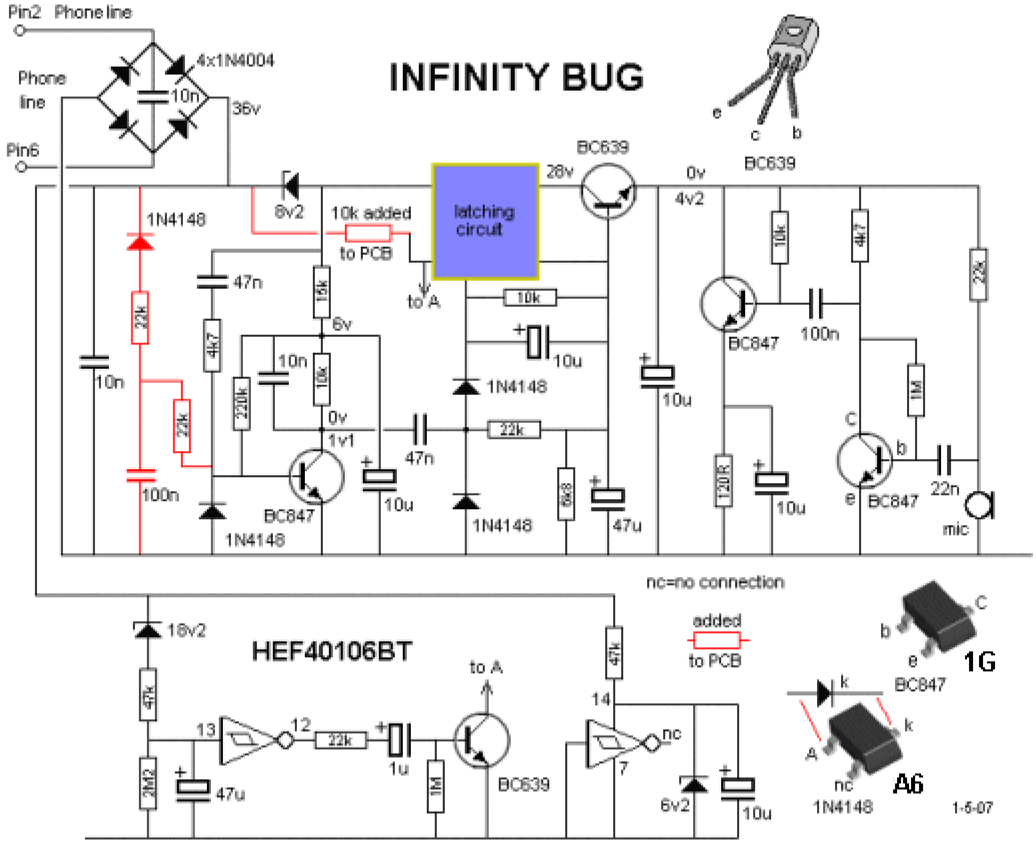
2u2
FLICKER
4u7
LED
BC547
BD679
12V ZENER
74C14
8 x 1N4148
1N4001
ARC WELDER mk2

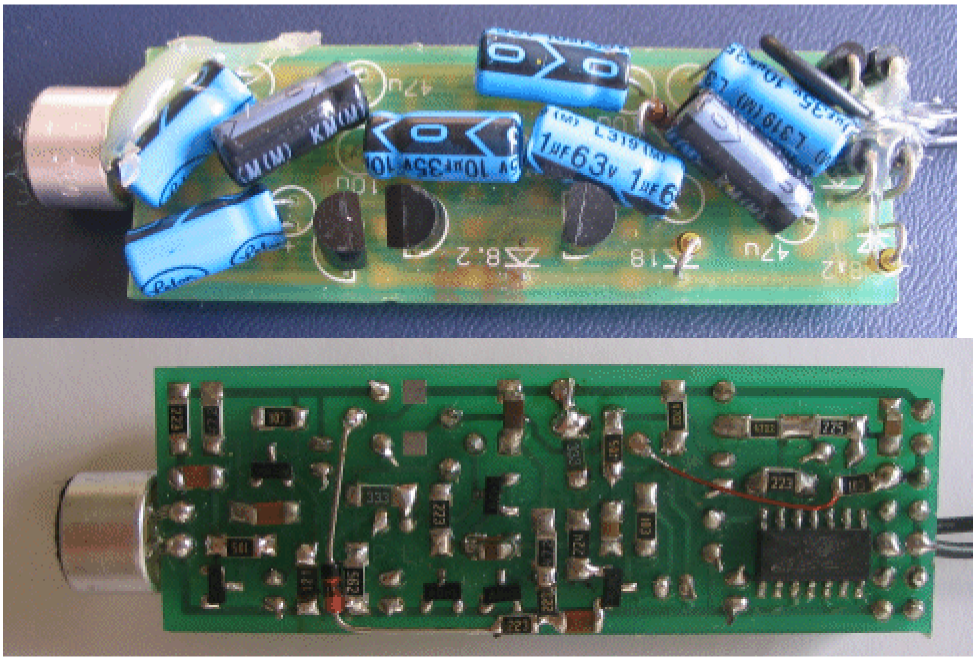
Field strength Meter MkII



A field strength meter is a very handy piece of test equipment to determine the output of a transmitter. Talking Electronics website describes a number of Test Equipment projects to help with developing your projects.

INFINITY BUG

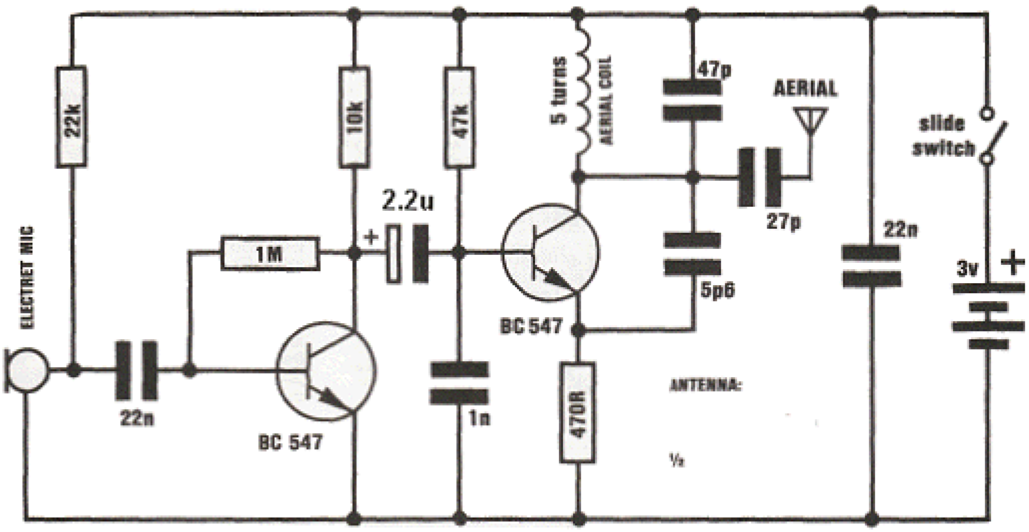




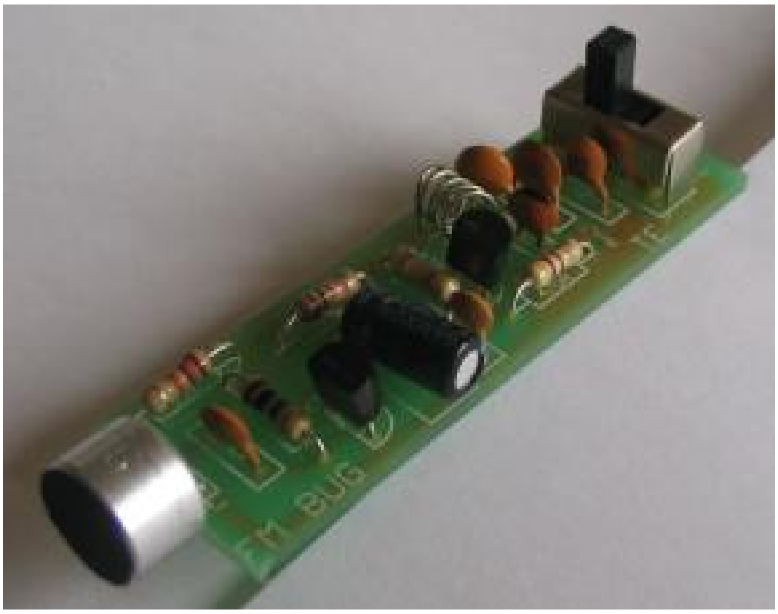
THE SURFACE-MOUNT COMPONENTS OF THE INFINITY BUG

The Infinity Bug sits on a remote phone and when the handset is returned to the rest position, the caller whistles down the line and a very sensitive microphone connected to the infinity bug is activated and any audio within 5 metres is detected.

FM BUG

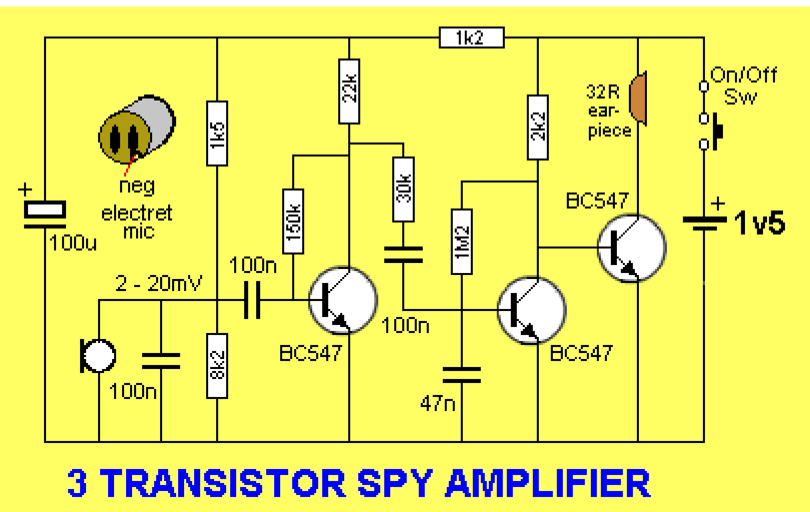


FM BUG CIRCUIT

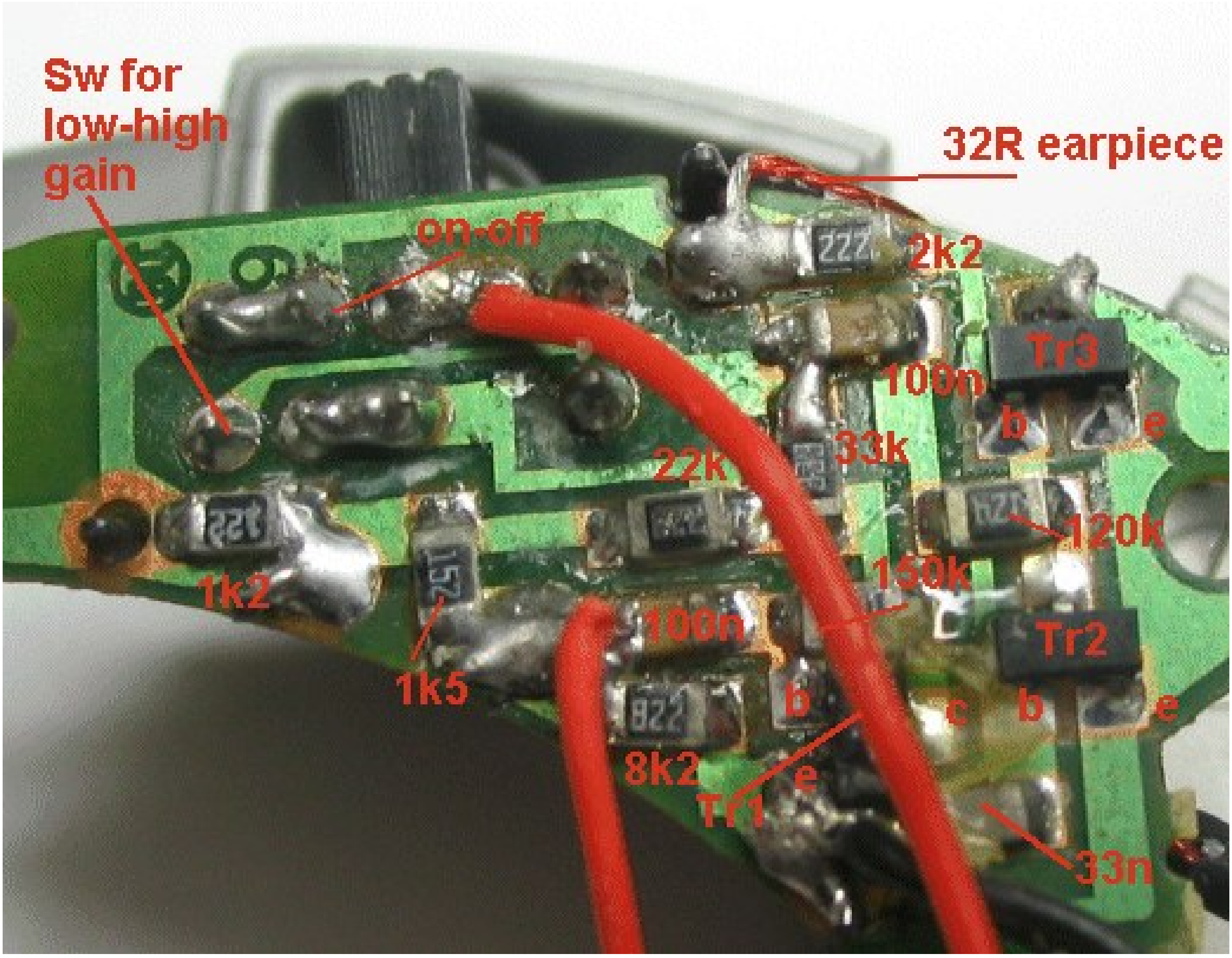


FM TRANSMITTER - 88MHz - 108MHz

3-Transistor Amplifier

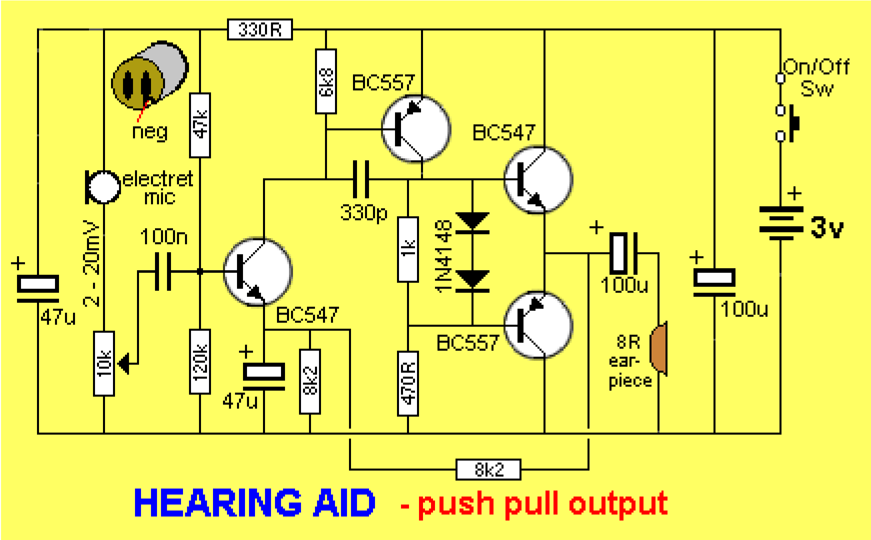


3 TRANSISTOR SPY AMPLIFIER

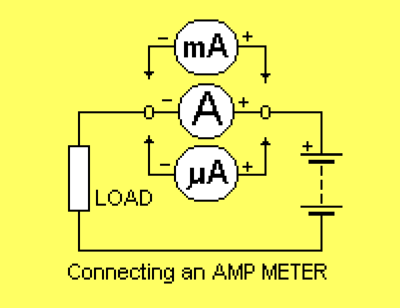


The surface-mount 3-Transistor amplifier

HEARING AID

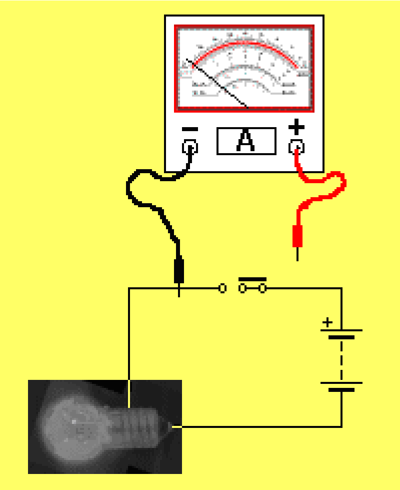


THE AMMETER



(0 - 1uA uses a 1uA movement)

The ammeter is placed in SERIES with one lead of a circuit. It must be placed around the correct way so the needle moves up-scale.
An ammeter is really a microamp-meter (it's called a movement - generally a 0-30 micro-amp movement) with a SHUNT (a thick piece of wire) across the two terminals.
To cover the range of current used in electronic circuits, there are basically 3 types of amp-meters (or 3 ranges):
0 - 1 amp (0 - 1A)
0 - 1milliamp (0 - 1mA)
0 - 1 microamp (0 - 1uA)
In each range you can get many different scales, such as:
0 - 1A, 0 - 10A, and higher
0 - 10mA, 0 - 100mA, 0-250mA, 0-500mA
0 - 1uA, 0 - 100uA, 0 - 500uA



Connecting an AMMETER

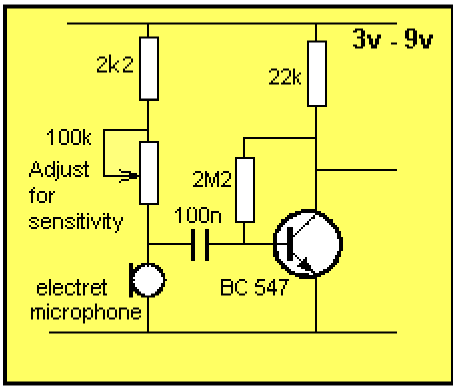
An ammeter is never connected across a battery or the supply rails of a project as this will create a SHORT-CIRCUIT and a large current will flow to either burn-out the meter or bend the pointer.
However, you need to know which way to connect a meter so that it reads up-scale.
This is how you do it:
Remember this simple fact: Current flows through the meter from the +ve lead to the -ve lead and this means the leads must be placed so that the positive lead sees the higher voltage.
Do not place an ammeter ACROSS a component. This will generally cause damage and in most cases it will not tell you anything.
You can check to see how much current is flowing through a circuit by **flicking** one lead of the ammeter onto the circuit and watching the needle. If it moves up-scale very quickly, you know excess current is flowing and a higher range should be chosen. If the needle moves fairly slowly up-scale, the chosen range may be correct.
Always start with a high range (0-1Amp for example) and if the needle moves a very small amount up the scale, another range can be chosen.
DON'T FORGET: Placing an ammeter on a circuit is a very dangerous thing because it is similar to playing with a jumper lead and represents a lead with a very small resistance. It is very easy to slip off a component and create a short-circuit. You have to be very careful.
Ammeters have to be connected across a "gap" or "cut" in a circuit and the easiest way to get a gap is across the on/off switch.
The accompanying diagram shows how to connect an ammeter.

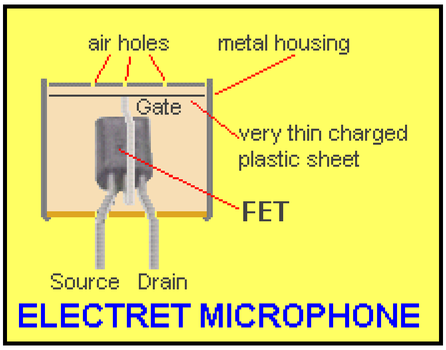
THE MICROPHONE

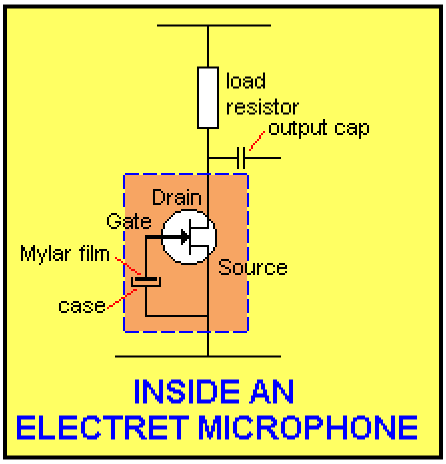
Basically there are two different types. One PRODUCES a voltage and the other REQUIRES a voltage for its operation.
This means you need to supply energy to the second type and this is very important when you are designing a battery-operated circuit and need to have a very low quiescent current.
Here is a list of different types of microphones and their advantages:

SUPPLY VOLTAGE REQUIRED:
Electret Microphone - sometimes called a condenser microphone. Requires about 2-3v @ about 1mA. Extremely good reproduction and sensitivity - an ideal choice. Output - about 10 - 20mV
Carbon Microphone - also called a telephone insert or telephone microphone. Requires about 3v - 6v. Produces about 1v waveform. Not very good reproduction. Ok for voice.
NO SUPPLY VOLTAGE REQUIRED:
Crystal Microphone - also called a Piezo microphone. Produces about 20-30mV Produces a very "tinny" sound - like talking into a tin.
Dynamic Microphone - also called a Moving-Coil, Moving-Iron, Magnetic Microphone or Ribbon Microphone. Very good reproduction. Produces about 1mV. A speaker can be used as a microphone - it is called a Dynamic Mic. or Magnetic mic. - output about 1mV

If a microphone produces about 20mV under normal conditions, you will need a single stage of amplification. If the microphone produces only 1mV under normal conditions, you will need two stages of amplification.
The circuits below show the first stage of amplification and the way to connect the microphone to the amplifier.





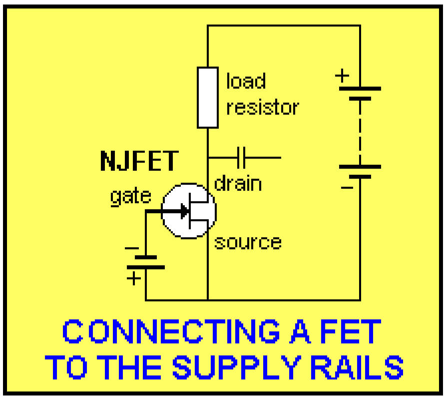


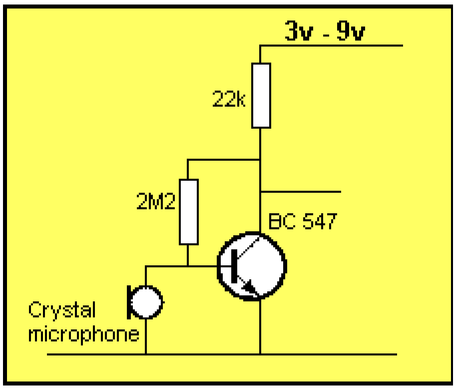
Connecting an electret microphone.

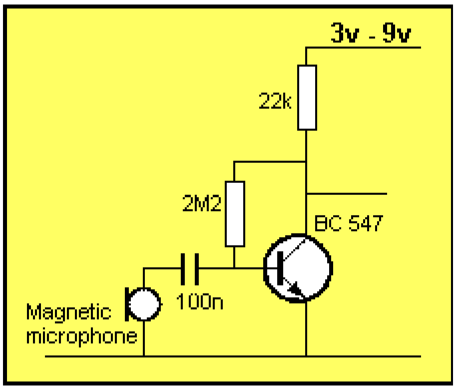
The 100n capacitor separates the voltage needed by the microphone (about 1v) from the 0.6v base voltage. A good electret microphone can hear a pin drop at 2 metres. A poor quality electret mic produces crackles in the background like bacon and eggs frying.

The internal construction of an electret microphone

Air enters the electret mic via the top holes and moves the thin mylar sheet. This changes the distribution of the charges on the plastic and the changes is passes down the Gate lead to the FET. The FET amplifies the signal and the result is available on the Drain lead.







Connecting a Crystal microphone

The crystal microphone has an almost infinite impedance - that's why it can be connected directly to the base of the transistor.
The magnetic microphone has a very low internal resistance and needs a capacitor to separate it from the base of the amplifying stage. If it is connected directly, it will reduce the base voltage to below 0.7v and the transistor will not operate.

PIEZO DIAPHRAGM

You can also use a piezo diaphragm as a microphone. It produces a very “tinny” sound but it is quite sensitive.
Some diaphragms are more sensitive than others, but the sound quality is always terrible.

MICROCONTROLLERS

Microcontrollers are the way of the future. Most of the basic theory you will learn for the individual components in this ebook will become very handy when you need to design a circuit.
As a circuit becomes more and more complex, you have a decision to make. Do you want to use lots of individual components or consider using a microcontroller?
Talking Electronics website has a number of projects using individual components and this is the only way the project can be designed. But when it comes to “timing” and requiring an output to produce a HIGH for a particular length of time after an action has taken place, the circuit may require lots of components.

This is where the brilliance of a microcontroller comes in.

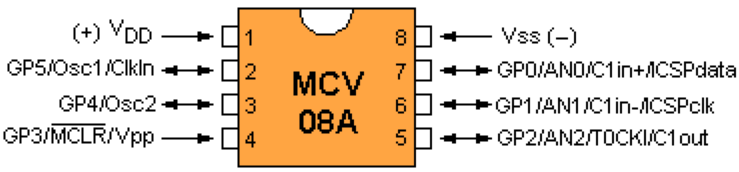
It can be programmed to produce and output after a sequence of events and the circuit looks “magic.” Just one component does all the work and a few other components interface the inputs and output to the chip.

The second special thing about micros is the program.
This has been produced by YOU and it can be protected from “prying eyes” by a feature known as “code protection.”
This gives you exclusive rights to reproduce the project and all your hard work can be rewarded by volume sales.

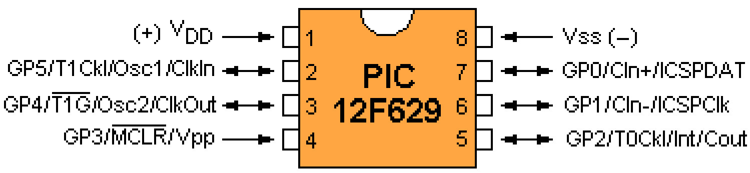
This is the future.

Talking Electronics website has a number of very simple projects using microcontrollers and these chips all belong to the PIC family of micros.

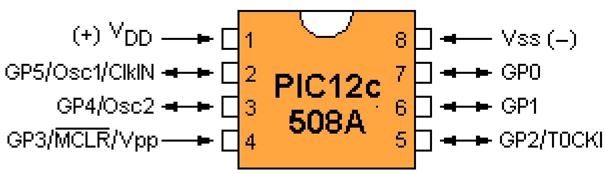
These chips are very easy to program as they only have 33 - 35 instructions and they can perform amazing things.
See the Talking Electronics website for project using these micros.
The three micros covered on the website are: PIC12F629, PIC16F84 and PIC16F628. The MCV08A is a Chinese version of the PIC12F629 and has some extra features and some of the features in the PIC12F629 are not present. But the cost is considerably lower than the PIC12F629. The Chinese get special deals all the time.



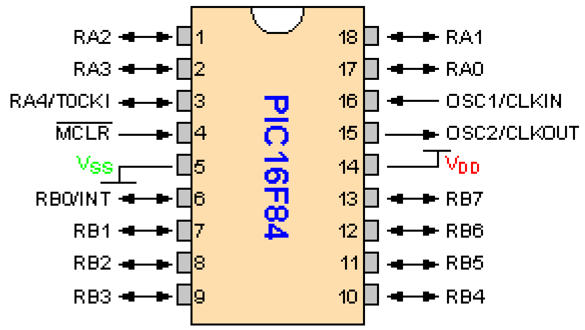
MCV08A Pinout

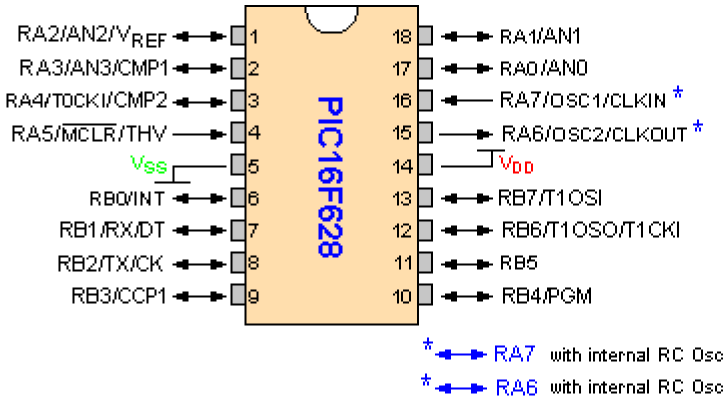


PIC12F629 Pinout



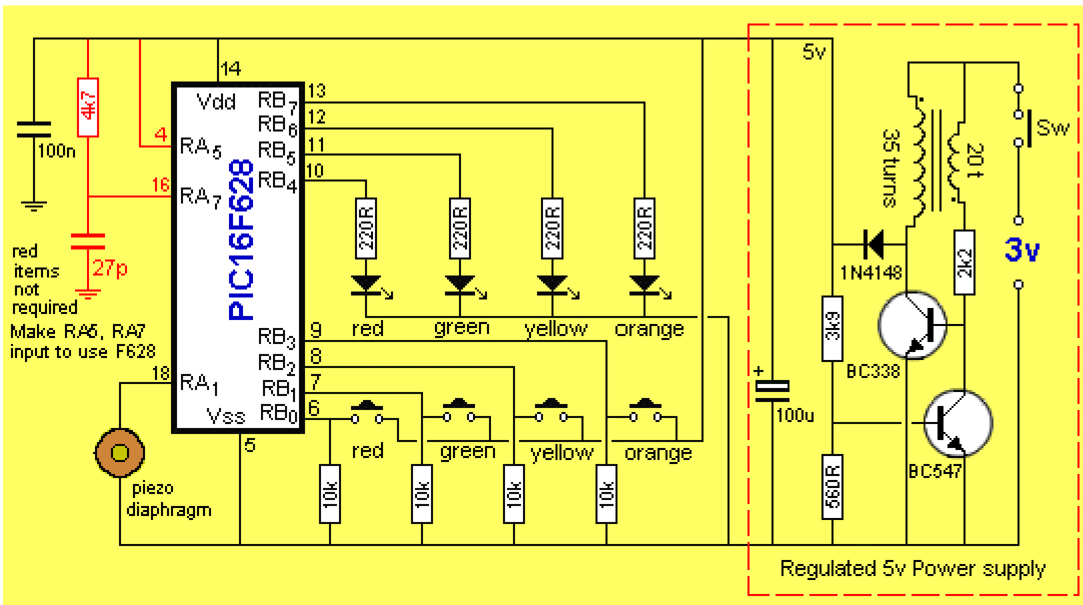
PIC12c508A PIC12c509 Pinout





HERE IS A PROJECT USING A MICROCONTROLLER:

SIMON



SIMON PROJECT USING PIC16F628

SIMON is the simple game where you repeat a sequence of flashing coloured lights. All the "workings" of the project are contained in the program (in the PIC16F628 microcontroller) and the program is provided on Talking Electronics website. See **Simon** project for more details.

This completes **Data Book 1**. Look out for more e-books on Talking Electronics website:

http://www.talkingelectronics.com

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