555 and 556 Timer Circuits
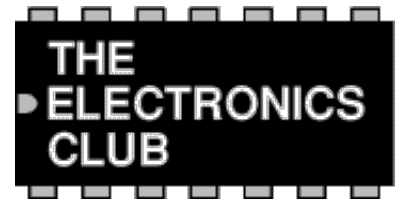
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Introduction

The 8-pin 555 timer must be one of the most useful ICs ever made and it is used in many projects. With just a few external components it can be used to build many circuits, not all of them involve timing!

A popular version is the NE555 and this is suitable in most cases where a '555 timer' is specified. The 556 is a dual version of the 555 housed in a 14-pin package, the two timers (A and B) share the same power supply pins. The circuit diagrams on this page show a 555, but they could all be adapted to use one half of a 556.

Low power versions of the 555 are made, such as the ICM7555, but these should only be used when specified (to increase battery life) because their maximum output current of about 20mA (with a 9V supply) is too low for many standard 555 circuits. The ICM7555 has the same pin arrangement as a standard 555.

The circuit symbol for a 555 (and 556) is a box with the pins arranged to suit the circuit diagram: for example 555 pin 8 at the top for the +Vs supply, 555 pin 3 output on the right. Usually just the pin numbers are used and they are not labelled with their function.

The 555 and 556 can be used with a supply voltage (Vs) in the range 4.5 to 15V (18V absolute maximum).

Standard 555 and 556 ICs create a significant 'glitch' on the supply when their output changes state. This is rarely a problem in simple circuits with no other ICs, but in more complex circuits a **smoothing capacitor** (eg 100µF) should be connected across the +Vs and 0V supply near
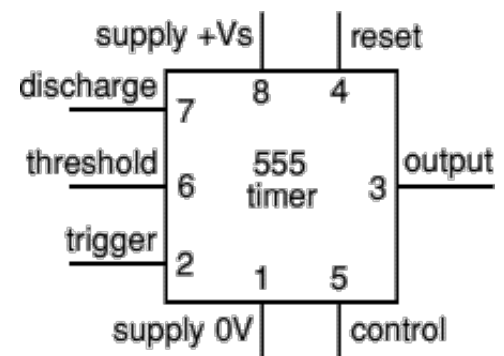
Example circuit symbol (above)

Actual pin arrangements (below)

the 555 or 556.

The input and output pin functions are described briefly below and there are fuller explanations covering the various circuits:

- Astable - producing a square wave
- Monostable - producing a single pulse when triggered
- Bistable - a simple memory which can be set and reset
- Buffer - an inverting buffer (Schmitt trigger)

Datasheets are available from:

- DatasheetArchive.com
- Datasheets.org.uk
- DatasheetCatalog.com
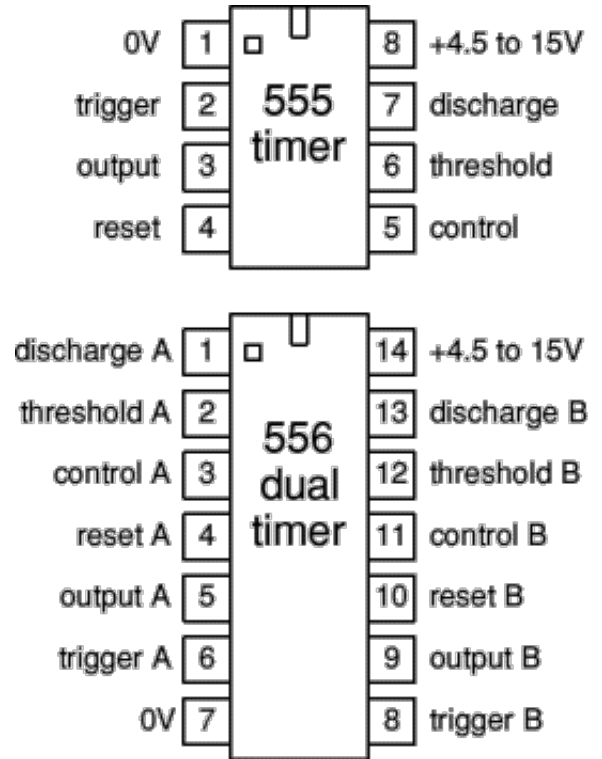
There is more information about 555 timers and their circuits on the Electronics in Meccano website.
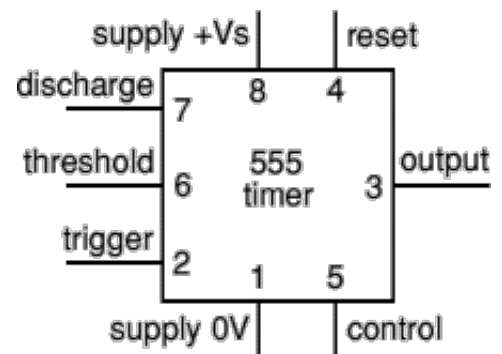
Inputs of 555/556

Trigger input: when < $\frac{1}{3}$ Vs ('active low') this makes the output high (+Vs). It monitors the discharging of the timing capacitor in an astable circuit. It has a high input impedance > 2MΩ.

Threshold input: when > $\frac{2}{3}$ Vs ('active high') this makes the output low (0V)*. It monitors the charging of the timing capacitor in astable and monostable circuits. It has a high input impedance > 10MΩ.

* providing the trigger input is > $\frac{1}{3}$ Vs, otherwise the trigger input will override the threshold input and hold the output high (+Vs).

Reset input: when less than about 0.7V ('active low') this makes the output low (0V), overriding other inputs. When not required it should be connected to +Vs. It has an input impedance of about 10kΩ.

Control input: this can be used to adjust the threshold voltage which is set internally to be $\frac{2}{3}$ Vs. Usually this function is not required and the control input is connected to 0V with a 0.01µF capacitor to eliminate electrical noise. It can be left unconnected if noise is not a problem.

The **discharge pin** is not an input, but it is listed here for convenience. It is connected to 0V when the timer output is low and is used to discharge the timing capacitor in astable and monostable circuits.

Output of 555/556

The output of a standard 555 or 556 can sink and source up to 200mA. This is more than most ICs and it is sufficient to supply many output transducers directly, including LEDs (with a resistor in series), low current lamps, piezo transducers, loudspeakers (with a capacitor in series), relay coils (with diode protection) and some motors (with diode protection). The output voltage does not quite reach 0V and +Vs, especially if a large current is flowing.

To switch larger currents you can connect a transistor.

The ability to both sink and source current means that two devices can be connected to the output so that one is on when the output is low and the other is on when the output is high. The top diagram shows two LEDs connected in this way. This arrangement is used in the Level Crossing project to make the red LEDs flash alternately.
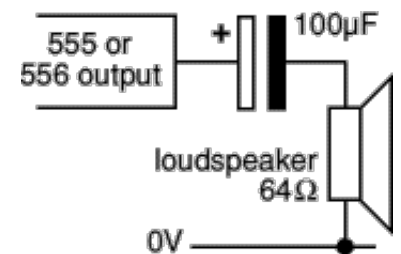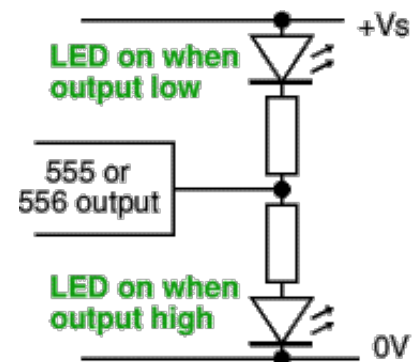
Loudspeakers

A loudspeaker (minimum resistance 64Ω) may be connected to the output of a 555 or 556 astable circuit but a capacitor (about 100µF) must be connected in series. The output is equivalent to a steady DC of about ½Vs combined with a square wave AC (audio) signal. The capacitor blocks the DC, but allows the AC to pass as explained in capacitor coupling.

Piezo transducers may be connected directly to the output and do not require a capacitor in series.

Relay coils and other inductive loads

Like all ICs, the 555 and 556 must be protected from the brief high voltage 'spike' produced when an inductive load such as a relay coil is switched off. The standard protection diode must be connected 'backwards' across the the relay coil as shown in the diagram.
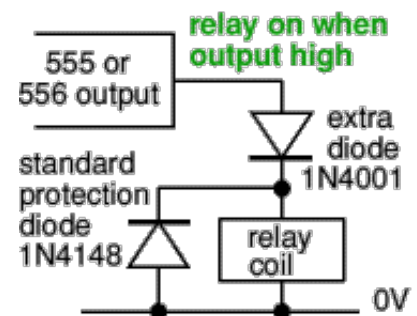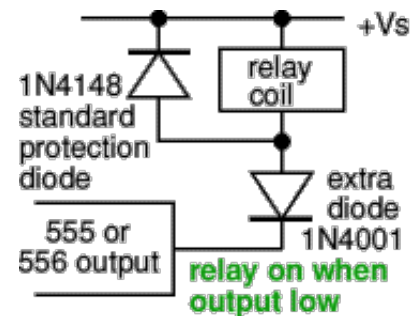
However, **the 555 and 556 require an extra diode** connected in series with the coil to ensure that a small 'glitch' cannot be fed back into the IC. Without this extra diode monostable circuits may re-trigger themselves as the coil is switched off! The coil current passes through the extra diode so it must be a 1N4001 or similar rectifier diode capable of passing the current, a signal diode such as a 1N4148 is usually **not** suitable.

555/556 Astable

An astable circuit produces a 'square wave', this is a digital waveform with sharp transitions between low (0V) and high (+Vs). Note that the durations of the low and high states may be different. The circuit is called an astable because it is not stable in any state: the output is continually changing between 'low' and 'high'.

555 astable output, a square wave
(Tm and Ts may be different)

The [time period](#) (T) of the square wave is the time for one complete cycle, but it is usually better to consider [frequency](#) (f) which is the number of cycles per second.

$$T = 0.7 \times (R1 + 2R2) \times C1 \quad \text{and} \quad f = \frac{1.4}{(R1 + 2R2) \times C1}$$

555 astable circuit

T   = time period in seconds (s)
f   = frequency in hertz (Hz)
R1 = resistance in ohms (Ω)
R2 = resistance in ohms (Ω)
C1 = capacitance in farads (F)

The time period can be split into two parts: **T = Tm + Ts**
Mark time (output high): **Tm = 0.7 × (R1 + R2) × C1**
Space time (output low): **Ts = 0.7 × R2 × C1**

Many circuits require Tm and Ts to be almost equal; this is achieved if R2 is much larger than R1.

For a standard astable circuit Tm cannot be less than Ts, but this is not too restricting because the output can both sink and source current. For example an LED can be made to flash briefly with long gaps by connecting it (with its resistor) between +Vs and the output. This way the LED is on during Ts, so brief flashes are achieved with R1 larger than R2, making Ts short and Tm long. If Tm must be less than Ts a diode can be added to the circuit as explained under [duty cycle](#) below.

Choosing R1, R2 and C1

R1 and R2 should be in the range 1kΩ to 1MΩ. It is best to choose C1 first because capacitors are available in just a few values.

- **Choose C1** to suit the frequency range you require (use the table as a guide).
- **Choose R2** to give the frequency (f) you

555 astable frequencies			
C1	R2 = 10kΩ R1 = 1kΩ	R2 = 100kΩ R1 = 10kΩ	R2 = 1MΩ R1 = 100kΩ
0.001µF	68kHz	6.8kHz	680Hz
0.01µF	6.8kHz	680Hz	68Hz

require. Assume that R1 is much smaller than R2 (so that Tm and Ts are almost equal), then you can use:

$$R2 = \frac{0.7}{f \times C1}$$

0.1µF	680Hz	68Hz	6.8Hz
1µF	68Hz	6.8Hz	0.68Hz
10µF	6.8Hz	0.68Hz (41 per min.)	0.068Hz (4 per min.)

- **Choose R1** to be about a tenth of R2 (1kΩ min.) unless you want the mark time Tm to be significantly longer than the space time Ts.
- If you wish to use a **variable resistor** it is best to make it R2.
- If R1 is variable it must have a fixed resistor of at least 1kΩ in series (this is not required for R2 if it is variable).

Astable operation

With the output high (+Vs) the capacitor C1 is charged by current flowing through R1 and R2. The threshold and trigger inputs monitor the capacitor voltage and when it reaches $\frac{2}{3}$Vs (threshold voltage) the output becomes low and the discharge pin is connected to 0V.
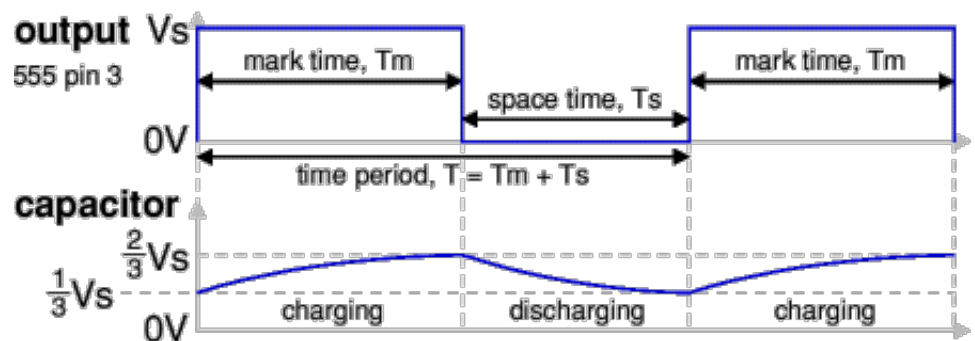
The capacitor now discharges

with current flowing through R2 into the discharge pin. When the voltage falls to $\frac{1}{3}$Vs (trigger voltage) the output becomes high again and the discharge pin is disconnected, allowing the capacitor to start charging again.

This cycle repeats continuously unless the reset input is connected to 0V which forces the output low while reset is 0V.

An astable can be used to provide the **clock signal** for circuits such as counters.

A **low frequency** astable (< 10Hz) can be used to flash an LED on and off, higher frequency flashes are too fast to be seen clearly. Driving a loudspeaker or piezo transducer with a low frequency of less than 20Hz will produce a series of 'clicks' (one for each low/high transition) and this can be used to make a simple metronome.

An **audio frequency** astable (20Hz to 20kHz) can be used to produce a sound from a loudspeaker or piezo transducer. The sound is suitable for buzzes and beeps. The natural (resonant) frequency of most piezo transducers is about 3kHz and this will make them produce a particularly loud sound.

Duty cycle

The duty cycle of an astable circuit is the proportion of the complete cycle for which the output is high (the mark time). It is usually given as a percentage.

For a standard 555/556 astable circuit the mark time (Tm) must be greater than the space time (Ts), so the duty cycle must be at least 50%:

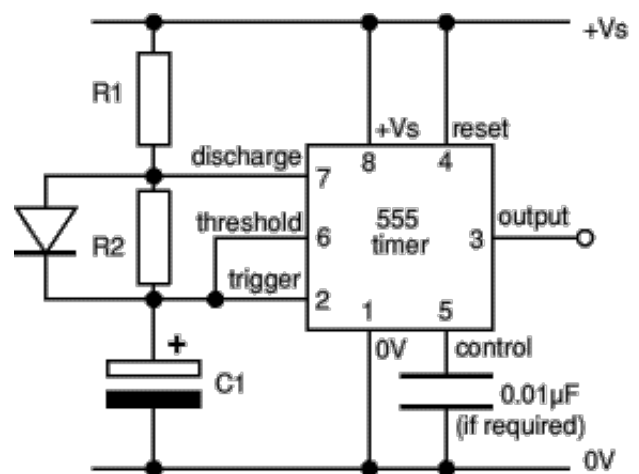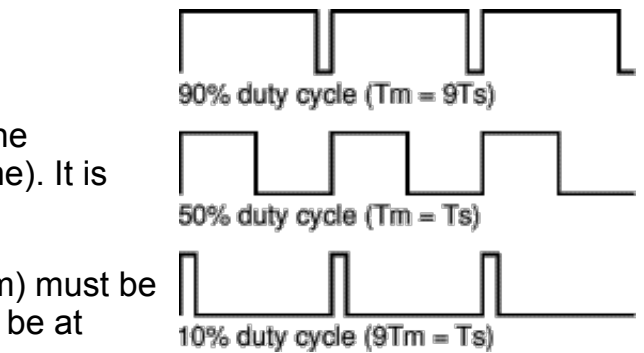$$\text{Duty cycle} = \frac{Tm}{Tm + Ts} = \frac{R1 + R2}{R1 + 2R2}$$

To achieve a duty cycle of less than 50% a diode can be added in parallel with R2 as shown in the diagram. This bypasses R2 during the charging (mark) part of the cycle so that Tm depends only on R1 and C1:

Tm = 0.7 × R1 × C1   (ignoring 0.7V across diode)
Ts = 0.7 × R2 × C1   (unchanged)

$$\text{Duty cycle with diode} = \frac{Tm}{Tm + Ts} = \frac{R1}{R1 + R2}$$

Use a [signal diode](#) such as 1N4148.

555 astable circuit with diode across R2

Example projects using 555 astable: [Flashing LED](#) | [Dummy Alarm](#) | [Heart-shaped Badge](#) | ['Random' Flasher](#)

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555/556 Monostable

A monostable circuit produces a single output pulse when triggered. It is called a monostable because it is stable in just **one** state: 'output low'. The 'output high' state is temporary.

555 monostable output, a single pulse

The duration of the pulse is called the **time period** (T) and this is determined by resistor R1 and capacitor C1:

time period, $T = 1.1 \times R1 \times C1$

T   = time period in seconds (s)
R1 = resistance in ohms (Ω)
C1 = capacitance in farads (F)
The maximum reliable time period is about 10 minutes.

Why 1.1? The capacitor charges to $2/3$ = 67% so it is a bit longer than the time constant (R1 × C1) which is the time taken to charge to 63%.

555 monostable circuit with manual trigger

- **Choose C1 first** (there are relatively few values available).
- **Choose R1** to give the time period you need. R1 should be in the range 1kΩ to 1MΩ, so use a fixed resistor of at least 1kΩ in series if R1 is variable.
- **Beware** that electrolytic capacitor values are not accurate, errors of at least 20% are common.
- **Beware** that electrolytic capacitors leak charge which substantially increases the time period if you are using a high value resistor - use the formula as only a very rough guide!
  For example the Timer Project should have a maximum time period of 266s (about 4½ minutes), but many electrolytic capacitors extend this to about 10 minutes!

Monostable operation

The timing period is triggered (started) when the **trigger** input (555 pin 2) is less than $1/3$ Vs, this makes the **output** high (+Vs) and the capacitor C1 starts to charge through resistor R1. Once the time period has started further trigger pulses are ignored.

The **threshold** input (555 pin 6) monitors the voltage across C1 and when this reaches $2/3$ Vs the time period is over and the **output** becomes low. At the same time **discharge** (555 pin 7) is connected to 0V, discharging the capacitor ready for the next trigger.

The **reset** input (555 pin 4) overrides all other inputs and the timing may be cancelled at any time by connecting reset to 0V, this instantly makes the output low and discharges the capacitor. If the

reset function is not required the reset pin should be connected to +Vs.

Power-on reset or trigger

It may be useful to ensure that a monostable circuit is reset or triggered automatically when the power supply is connected or switched on. This is achieved by using a capacitor instead of (or in addition to) a push switch as shown in the diagram.

The capacitor takes a short time to charge, briefly holding the input close to 0V when the circuit is switched on. A switch may be connected in parallel with the capacitor if manual operation is also required.

This arrangement is used for the trigger in the Timer Project.

Power-on reset or
trigger circuit
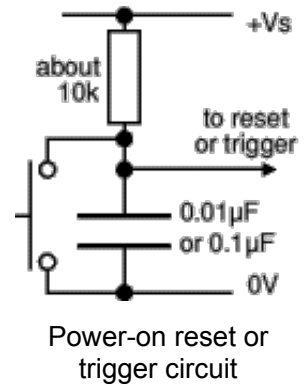
Edge-triggering

If the trigger input is still less than $^1/_3$ Vs at the end of the time period the output will remain high until the trigger is greater than $^1/_3$ Vs. This situation can occur if the input signal is from an on-off switch or sensor.

The monostable can be made **edge triggered**, responding only to **changes** of an input signal, by connecting the trigger signal through a capacitor to the trigger input. The capacitor passes sudden changes (AC) but blocks a constant (DC) signal. For further information please see the page on capacitance. The circuit is 'negative edge triggered' because it responds to a sudden fall in the input signal.

edge-triggering circuit
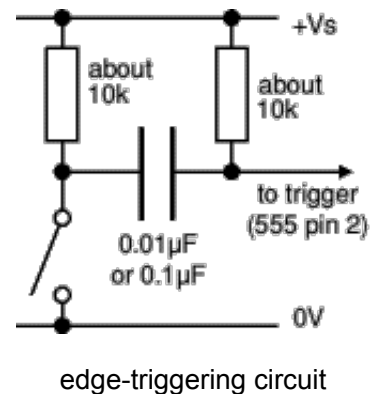
The resistor between the trigger (555 pin 2) and +Vs ensures that the trigger is normally high (+Vs).

Example projects using 555 monostable: Adjustable Timer | Electronic 'Lock' | Light-sensitive Alarm

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# 555/556 Bistable (flip-flop) - a memory circuit

The circuit is called a bistable because it is stable in **two** states: output high and output low. It is also known as a 'flip-flop'.

It has two inputs:

- **Trigger** (555 pin 2) makes the **output high**. Trigger is 'active low', it functions when < $^1/_3$ Vs.
- **Reset** (555 pin 4) makes the **output low**. Reset is 'active low', it resets when < 0.7V.

The power-on reset, power-on trigger and edge-triggering circuits can all be used as described above for the [monostable](#).

Example projects using 555 bistable: [Quiz](#) | [Model Railway Signal](#)
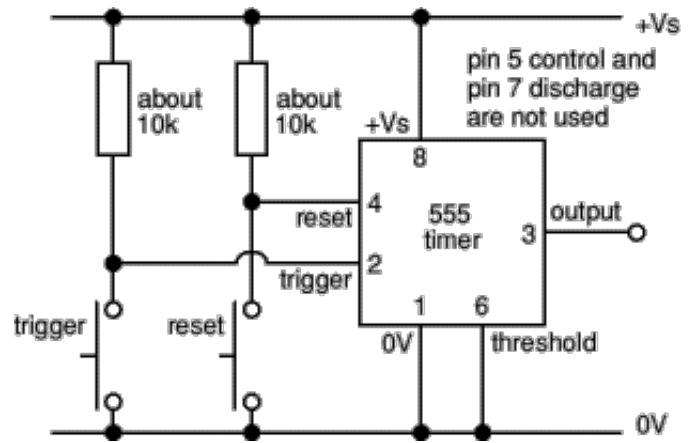
555 bistable circuit

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555/556 Inverting Buffer (Schmitt trigger) or NOT gate

The buffer circuit's input has a very high impedance (about 1MΩ) so it requires only a few µA, but the output can sink or source up to 200mA. This enables a high impedance signal source (such as an LDR) to switch a low impedance output transducer (such as a lamp).

It is an **inverting buffer** or [NOT gate](#) because the output logic state (low/high) is the inverse of the input state:

- **Input low** (< $^1/_3$ Vs) makes **output high**, +Vs
- **Input high** (> $^2/_3$ Vs) makes **output low**, 0V

When the input voltage is between $^1/_3$ and $^2/_3$ Vs the output remains in its present state. This intermediate input region is a deadspace where there is no response, a property called **hysteresis**, it is like backlash in a mechanical linkage. This type of circuit is called a **Schmitt trigger**.

If high sensitivity is required the hysteresis is a problem, but in many circuits it is a helpful property. It gives the input a high immunity to noise because once the circuit output has switched high or low the input must change back by at least $^1/_3$ Vs to make the output switch back.
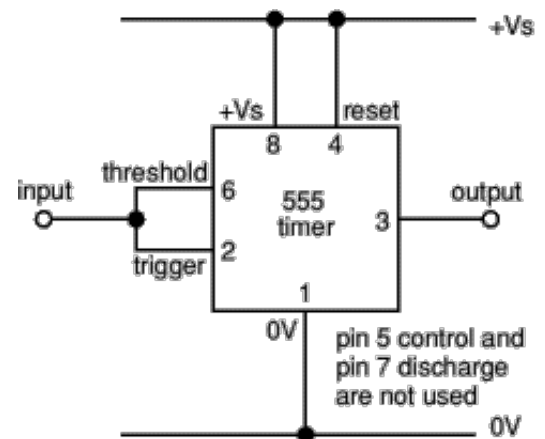
555 inverting buffer circuit (a NOT gate)
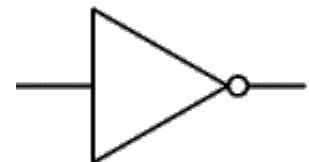
NOT gate symbol

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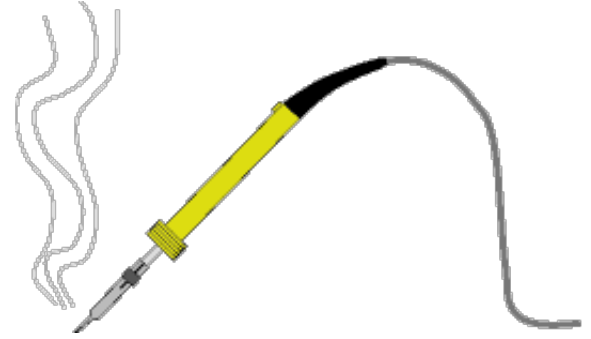
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