# Monostables, Bistables and Multistables

## Introduction

Systems for generating and processing pulses make extensive use of **multivibrators**; these are circuits which have two states. There are three types of multivibrator: **astable** (free-running), **monostable** (one-shot), and **bistable** (flip-flop). There are many ways of implementing each type, and many variants.

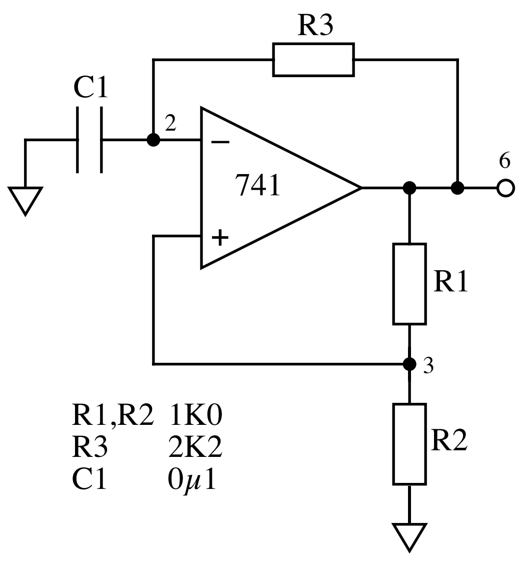
Note: All the circuits in this document operate by using positive feedback to drive the op-amp into saturation, it is therefore not the case that the two inputs of the op-amp can be assumed to be at the same potential. See the comments on Worksheet 10 regarding op-amps vs comparators.

## Astable Multivibrator

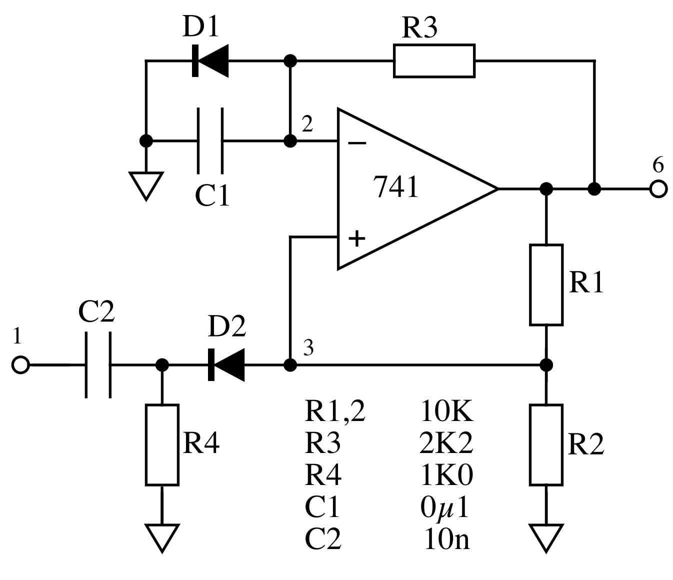
The two states of circuit 11.1 are only stable for a limited time and the circuit switches between them with the output (node 6) alternating between positive and negative saturation values $\pm V_S$. Analysis of this circuit starts with the assumption that at time $t = 0$ the output has just switched to state 1 ($V_6 = +V_S$), and the transition would have occurred when

$$V_2 = V_6(\text{state } 0)\frac{R_2}{R_1 + R_2} \quad \text{where} \quad V_6(\text{state } 0) = -V_S. \tag{11.1}$$

In state 1, the voltage across the capacitor increases as a result of current flowing through $R_3$ from




Circuit 11.1 Astable Multivibrator




Circuit 11.2 Monostable Multivibrator

its initial value $V_2(t=0) = -V_S R_2 / (R_1 + R_2)$ until

$$V_2(t_0) = V_3(\text{state 1}) = +V_S \frac{R_2}{R_1 + R_2}. \tag{11.2}$$

when the output from the op-amp switches back to state 0. Then the capacitor discharges until, at time $t = 2t_0$, the output switches from state 0 back to state 1, and the whole sequence restarts. It is straightforward to show that

$$t_0 = C_1 R_3 \ln\left(1 + 2\frac{R_2}{R_1}\right) \tag{11.3}$$

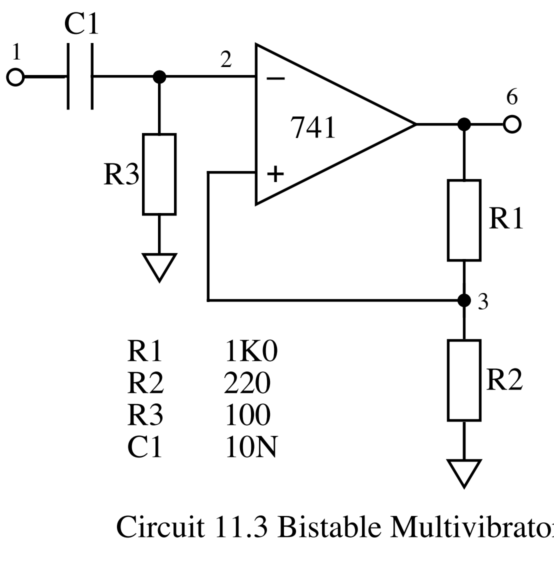
## Monostable Multivibrator

A diode connected in parallel with the timing capacitor of the astable circuit will prevent the inverting input of the amplifier from going positive (circuit 11.2). The (permanently) stable state of this circuit has $V_6 = +V_S$ with node 2 clamped to $\sim 0.6\ V$ by diode $D_1$, and node 3 at

$$V_3(\text{state 1}) = 0.6\ \text{V} + V_S \frac{R_4}{R_1 + R_4} \tag{11.4}$$

where it has been assumed that $R_2 \gg R_4$ to simplify the expression. A sufficiently large pulse at node 3, generated by a negative-going edge at the trigger input (node 1), will switch the circuit into its temporary state ($V_6 = -V_S$) and, after a delay

$$t_0 = C_1 R_3 \ln\left(1 + \frac{R_2}{R_1}\right) \tag{11.5}$$




Circuit 11.3 Bistable Multivibrator

while $C_1$ charges through $R_3$, the circuit switches back to its stable state.

## Bistable Multivibrator

Circuit 11.3 shows an op-amp configured as a bistable multivibrator. The two stable states are $V_6 = \pm V_{SS}$ and the circuit is switched between these by a pulse of appropriate polarity applied to the inverting terminal (node 2) of the op-amp.

## Required Reading

Study the datasheet for the 555 timer integrated circuit. There are more explanations and examples on the WWW at:
<http://newton.ex.ac.uk/teaching/CDHW/Electronics2/ElectronicsResources.html>.

---

Exercise 11.1 Show that the voltage across a capacitor $C_1$, being charged through a resistor $R_3$ from a supply voltage $V_S$ is

$$V_2(t) = V_S + \left[V_2(0) - V_S\right]\exp\left(-t/C_1R_3\right)$$

and hence derive equation 11.3

Exercise 11.2 What is the frequency of operation of circuit 11.1? Assume that $V_S = 10\text{ V}$ and plot a graph showing how $V_2$ and $V_3$ vary with time for this circuit.

Answer: 2 kHz

Exercise 11.3 What amplitude of square wave is required to switch circuit 11.2 if $V_S = 10\text{ V}$?

Answer: At least one volt peak-to-peak.

Exercise 11.4 What is the minimum ramp-rate (*i.e.* $\mathrm{d}V_1/\mathrm{d}t$) required at node 1 to switch circuit 11.2 if $V_S = 10\text{ V}$?

Answer: About 100 kV $\mathrm{s}^{-1}$ negative-going.

Exercise 11.5 Design an astable with a free-running frequency of 1.5 kHz and a duty-cycle (*i.e.* ratio of times spent in the two states) of 3:1. Base your circuit around a 555 timer and use a 0.1 $\mu$F timing capacitor.

Answer: Use figure 4 in LM555 datasheet with $R_A = 4.8\text{ k}\Omega$ and $R_B = 2.4\text{ k}\Omega$.

---