FACTFILE:

GCE TECHNOLOGY & DESIGN

1.14 CALCULATIONS AND 1.17 ELECTRONIC SYSTEMS: PART 7

Rewarding Learning

Monostable and Astable

Learning Outcomes:

Students should be able to:

- demonstrate knowledge and understanding of the following system:
  - monostable and astable circuits using 555 timer;
  - incorporate these devices into applications to meet specified criteria;
- and, from 1.14 Calculations:
- use knowledge and understanding of formulas, and given information to complete calculations for:
  - time period, T =I/f;
  - time period, T=1.1CxR of output of monostable circuits using 555 timer;
  - frequency, f=1.44/(R1+2R2)C of output of astable circuits using 555 timer, to include mark/space ratio.

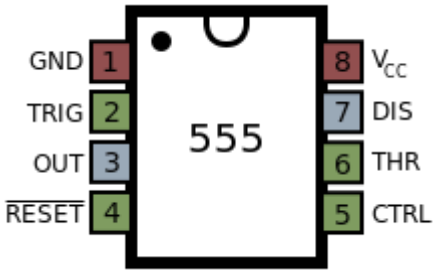
Students need to know the relevant formulas as we will not provide these in the assessment.

Course Content

The 555 Timer

The 555 timer is an integrated circuit used in a variety of applications. For instance, the 555 may be used to provide time delays or generate a continuous stream of pulses. The particular function is controlled by the external components connected to the 555 timer.

The 555 timer is available in an 8 pin DIL package with the following connections:

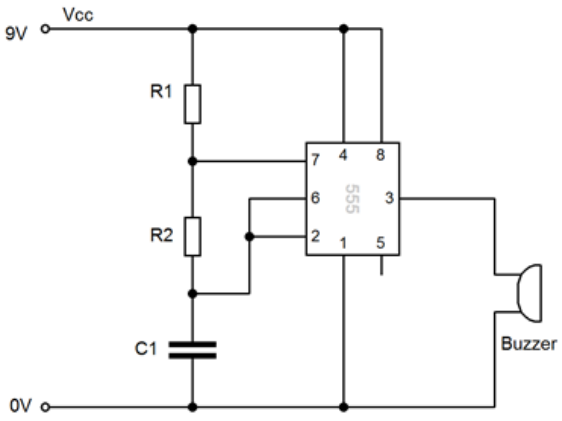


It is necessary to have an understanding of the operation of the 555 timer and also useful to be aware of the function of the various connections on the device.

Pin	Name	Function
1	Ground	0 V
2	Trigger	The voltage on this pin determines when the output goes high and the timing interval starts.
3	Output	Output voltage. This is either high, sometimes called MARK (close to the + supply voltage) or low sometimes called SPACE (close to 0V).
4	Reset	Normally this is held high. If this is connected to 0V, the output pulses stop.
5	Control	Not used in this specification
6	Threshold	This is connected to the timing capacitor and forms part of the timing circuit.
7	Discharge	The voltage on this pin is controlled by the internal circuit of the 555 timer. When this pin is high the timing capacitor charges; when the timer brings it low, the timing capacitor discharges.
8	Vcc	Positive supply voltage (typically +3 to +15 V)

The Astable

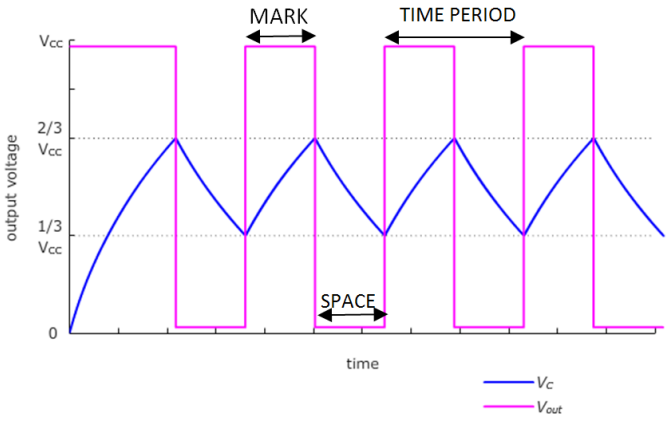
An astable (also known as an oscillator, a pulse generator or a clock) is a circuit which has no stable states – the digital voltage produced alternates between High (+) and Low (0V).



Typical Astable Circuit

Operation: The resistors R1 and R2 serve to provide a path for the capacitor C to charge. The time taken for the capacitor to charge depends on the values of R1, R2 and C (the charging time constant). While the capacitor is charging, the output, pin 3 is high.

When the voltage across the capacitor reaches 2/3 Vcc, the output goes low, as does the voltage at pin 7. Since pin 7 is now low, the capacitor starts to discharge through R2. The time taken for the capacitor to discharge depends on the values of R2 and C (the discharging time constant). When the voltage across it falls to 1/3 Vcc, the output goes high again and pin 7 is no longer held low. The capacitor therefore begins to charge again and the process repeats.



Source: http://www.doctronics.co.uk/555.htm#pins

The Time Period T (the total time for a charge / discharge cycle) is given by:

T = (R1 + 2R2)C / 1.4 (T in seconds, R in Ω, C in Farads)

The frequency (or number of cycles per second) is given by f= 1/T or

f = 1.4 /(R1 + 2R2)C (f in hertz, R in Ω, C in Farads)

The time for which the output is high is sometimes called the Mark, and the time for which it is low is called the Space. The Mark/Space ratio = Mark time / Space Time. Note that since resistor R1 is present during charging, but not discharging, the charging time is longer that the discharging time. If R2 is chosen to be much larger than R1, then the Mark Time and Space Time are approximately equal, giving a Mark/Space ratio of approximately 1.

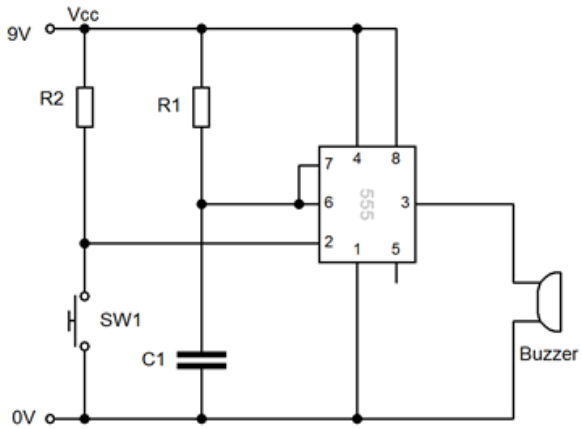
If a Mark/Space ratio of 1 is required (equal high and low times), then R2 » R1, so that R1 may be ignored in the above equations giving:

T=1.4R2C and f = 0.7 / R2C

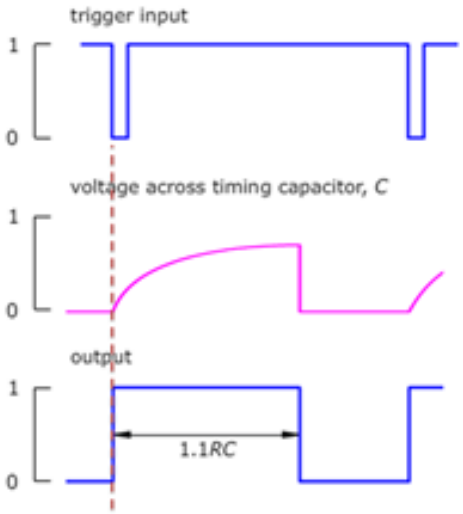
If it necessary to have a Time Period which may be easily changed, R2 may be replaced by a variable resistor or by a number of resistors that may be selected using a multi-throw switch.

The Monostable

A monostable (also known as a one shot) is a circuit in which one of the states is stable, but the other state is unstable (transient). A trigger causes the circuit to enter the unstable state. The circuit will return to the stable state after a set time.



Typical Monostable Circuit



Operation:
In this case only one external resistor, R1, is required in the timing circuit and the threshold (pin 6) is joined to discharge (pin 7). One rectangular output pulse is produced when the circuit is triggered by the falling (negative-going) edge of an external pulse applied to trigger (pin 2). It then returns to its one stable state ('low' output) to await the next trigger pulse. The trigger pulse can be obtained for example, by pressing the switch SW1, the operation being completed in a time which must be less than the output pulse time.

The time T of the output pulse can be shown to be given by:

T = 1.1R1 x C1 (T in seconds, R in Ω, C in Farads)

Revision Questions

1 An astable circuit based on a 555 timer shown in the figure below is to be used for a warning light

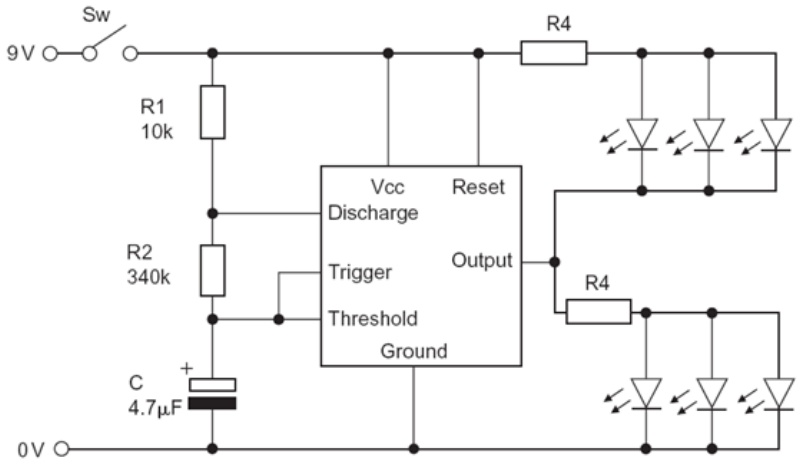


Figure 1

(i) Calculate the output frequency of the circuit shown in the figure above given that the time period T = C (R1+2R2) /1.44.

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(ii) Using the value from answer 1 (i) above, sketch and label the output waveform for the circuit in the figure above indicating the mark, space and period on the waveform.

Revision Questions

1 (iii) Explain, in detail, the operation of the warning light circuit shown in Figure 1.

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Quality of written communication will be assessed in this question.

(iv) Calculate the required value for the resistor R4 in the figure above if the LEDs shown are each designed to work at a forward voltage of 1.4 V and a current of 12 mA.

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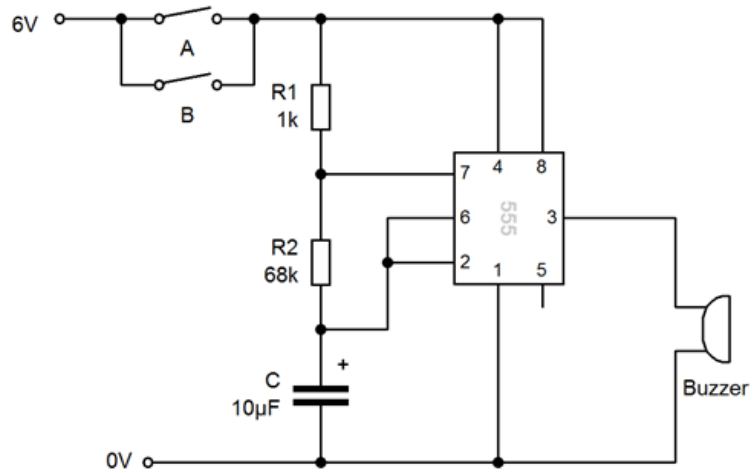
Source: CCEA AS Jan 2012

Revision Questions

2 The fire alarm circuit utilises a 555 astable circuit to control a buzzer.



(i) Explain what is meant by the term astable when referring to 555 timers.

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(ii) Calculate the output frequency f of the circuit shown in the figure above given that f = 1.44/C (R1 + 2R2)

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Revision Questions

2 (iii) Sketch and label the output waveform for the astable circuit in the figure above. Indicate the period, mark and space on the waveform.

(iv) Design a modification to the circuit shown in the figure above that will allow the frequency of the output to be adjusted.

Source: CCEA AS May 2010

Revision Questions

3 A 555 integrated circuit is connected to other components, including a variable resistor as shown in the figure below..

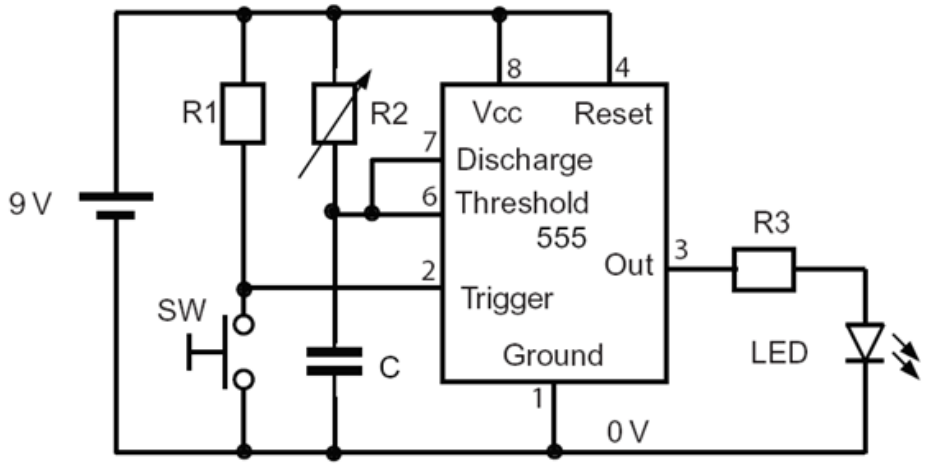

Figure 3

(ii) Describe the operation of the circuit shown in the figure above making reference to the components that control the timing.

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Quality of written communication will be assessed in this question

(iii) Calculate the range of the variable resistor R2 to illuminate the LED in Figure 3 for the periods ranging from 1 second to 5 seconds when C = 100 µF given that the Time Period T = 1.1 × C × R2 seconds.

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Source: CCEA AS Jan 2010

Revision Questions

4 A circuit based on a 555 timer is shown in the figure below.

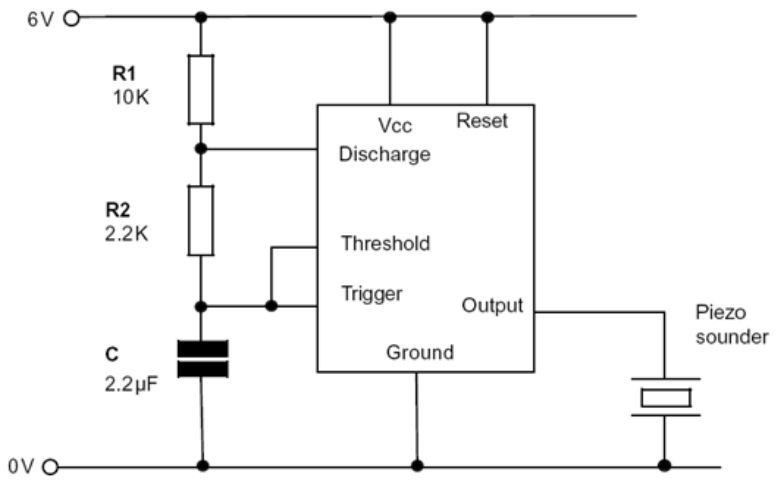

Figure 4

(i) State whether the circuit shown in the figure above is an open loop or closed loop system and justify your answer.

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(ii) Calculate the output frequency of the circuit shown in the figure above given that T = C (R1+2R2)/1.44.

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(iii) Explain the operation of the circuit shown in the figure above.

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Revision Questions

4 (iv) The circuit in the figure above is to be modified to enable a number of different output frequencies to be selected by operating a switch. Explain with the aid of a circuit diagram how this could be achieved and state a suitable type of switch.

Source: CCEA AS Jan 2009

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