CHAPTER 23

Electronics

INTRODUCTION 23.1

It was seen in the previous chapter that electricity is very important in modern society. Electronics is a relatively new branch of general electrical studies, which makes use of small-scale components and circuits. The development of electronics in the latter half of the twentieth century has led to many of our modern consumer electrical products and technology. Unlike the general use of electricity that dates back well over 150 years, modern electronics has expanded only since the invention of simple semiconductor devices in the early 1950s. The improvement in understanding of solid state physical devices has made possible micro-miniaturisation and very fast electronic circuit operations. These features are the basis of modern computer technology and the real start of what has been termed the 'information age'.

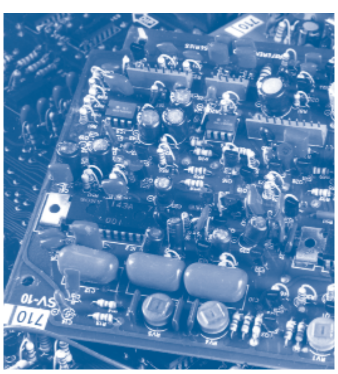
Electronic engineering today involves the use of many thousands of specialised components and circuits that have all developed from the early discoveries in semiconductor solid state physics. In this chapter we will look specifically at a set of basic electronic circuit components and their behaviour. It is from this basic set of components that electronic systems can be developed. This will be further discussed in Chapter 24. At the completion of this chapter, you will be able to answer questions like the following:

- Why do we have portable batteries but still need household electricity supplies?
- What is the difference between DC and AC voltages and currents?
- Is colour-blindness a problem for people working in electronics?
- How can some electronic devices be made so small that they can hardly be seen?
- Are electronic circuits, especially those of larger devices like TV sets and computers, really as complex as they look?

MEASUREMENT AND TEST INSTRUMENTS 23.2

Multimeters

Photo 23.1
Electronic circuit boards.



In the previous chapter, the basic electric measurement meters called the voltmeter and the ammeter were introduced. These instruments are most often used in fixed circuit applications or as stand-alone instruments to give a continuous voltage and current reading. In practical electronics a more versatile and portable measurement instrument is required. This is the **multimeter**. Its readout can be an analog needle over a scale or, more usually, a digital display readout. (See Photo 22.4 on page 483.) Modern multimeters provide numerous measurement quantities over a wide range of values, such as DC/AC voltage, DC/AC current, resistance and conductivity testing, frequency, diode conductance and capacitance. Unlike the older analog models which required the correct range of the quantity to be selected via a selector switch, newer digital models are often **auto-ranging**, which means that the input circuitry automatically senses the correct measurement range and produces an output that matches this range. For example, without altering the instrument, apart from selecting AC voltage, a technician is able to measure millivolts AC in a radio circuit, through to household domestic 240 volt AC mains.

It is always important to be aware of the measurement being made with a multimeter and check both the quantity being measured and the approximate range of the values before making any connection to a circuit. In any unknown measurement exercise it is good protection policy to select the instrument's highest scale setting and then adjust downward until an appropriate instrument scale reading is achieved. It is also often necessary on some multimeter models to adjust the input probe connectors on the face of the instrument and move them to different sockets when changing from low values to high values. The manual that comes with the multimeter will explain this. Recall also from the previous chapter that any measurement instrument should affect the circuit under test as little as possible. Especially with analog multimeters, this means that the instrument's **sensitivity range** should be as high as possible, with a value of 20 kΩ/V being regarded as the most useful in professional electronic measurement. Digital multimeters have the advantage that their sensitivity range is already very high due to the electronic integrated circuit components that comprise the internal circuitry.

Photo 23.2
CBL2 data-logger.

When using a multimeter to measure either DC or AC voltage, the probes should be placed in parallel or across the component in the circuit in exactly the same way as a conventional voltmeter. When using a multimeter to measure either DC or AC current, the probes will need to be placed in series with the component, as with a conventional ammeter. This may necessitate disconnecting one end of the component from the circuit and using the multimeter probes to remake the connection. When using a multimeter to measure resistance, it is often necessary, especially on analog models, to re-zero the meter. This means shorting the probes together and using the 'ohms adjust' knob to make sure that the needle of the multimeter actually reads zero resistance. There is a variety of different multimeters and it is always important to read the manual properly and take care in operating the instrument.

Data-loggers and sensors

You may be lucky enough to have the use of a set of measurement instruments that could make the automatic measurement of electrical and other physics quantities very easy. This is the laboratory **data-logger**; when coupled with electronic or other sensors and connected to a graphics calculator, this allows not only the recording of data over time intervals from milliseconds to months, but also the analysis of that data almost immediately. Common sensors such as current and voltage probes allow normal electrical circuit quantities to be logged, but a range of non-electrical attachments such as accelerometers, pressure sensors, temperature probes and rotation sensors allow an even greater range of physics measurements in your experiments. Photo 23.2 (a) shows an example of the Texas instruments CBL2 data-logger connected to the TI-83 Plus graphics calculator and sensors.

Photo 23.3
Power supplies.

Power supplies

A bench-top **power supply** is needed for electronic testing as it supplies the necessary DC/AC operating voltages for the components and circuit under test. Quite often these power supply units in the laboratory are referred to as power packs or rectifiers. How they are constructed will be further discussed in Section 23.6 and Chapter 31. One of the most important considerations in the use of bench-top power supplies is to avoid the voltage connector leads, the positive, negative or the AC leads, coming into contact and short-circuiting. Not only will this usually produce dangerous sparking, but the power supply itself may be damaged. The short circuit created will generally exceed the maximum current rating for which the power supply is designed and internal damage may occur if the unit is not fuse-protected or does not contain some form of current overload circuit-breaker. It is also important that you check that the voltage settings on the power supply are as low as possible before turning the instrument on. In general, changes made to any electrical circuit should only be made with its power supply connections turned off. This avoids very high voltage transient spikes from causing possible damage to the circuit components under test.

Cathode ray oscilloscope

Figure 23.1
Cathode ray tube assembly.

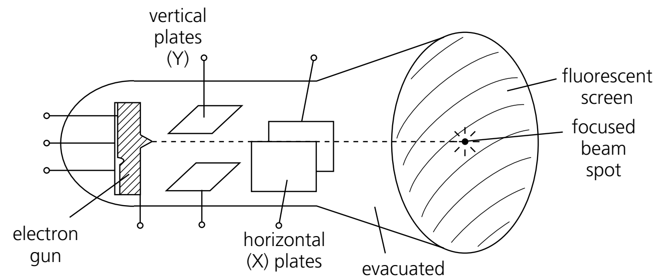
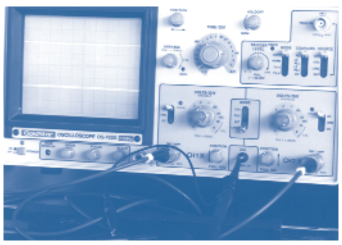
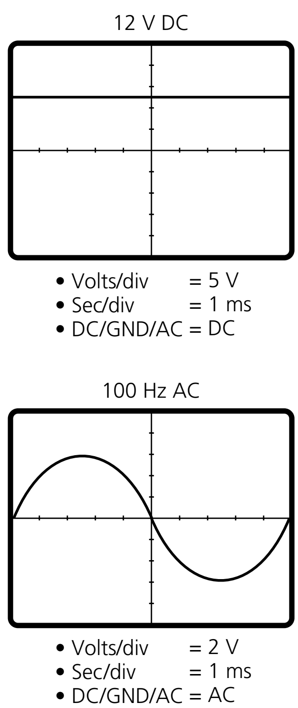


Photo 23.4
A dual beam oscilloscope.



Invented in 1897 by a German physicist, Karl Ferdinand Braun, the **cathode ray oscilloscope** (CRO) is an instrument used widely in electric and electronic circuits to display and make measurements on voltage waveforms. The CRO uses a very fast electron beam striking the face of a **cathode ray tube** (CRT), which is being deflected by rapidly changing magnetic and electric fields. The moving electron beam passes over the calibrated scale on the face of the CRT and allows measurements of voltage wave shape, amplitude and frequency. As well, it allows a simple visual inspection of the way the voltage may vary under different circuit settings. Within the evacuated cathode ray tube, an electron gun emits a narrow beam of electrons, which travel down the tube and strike a fluorescent screen at the front. Light is emitted and a bright spot is formed on the screen. (See Figure 23.1 and Photo 23.4.) This electron beam passes through a set of vertical deflection plates carrying a voltage proportional to the input voltage being measured. This can be expanded by the use of the 'vertical gain' control. At the same time the beam passes through a set of horizontal deflection plates across which is placed a regularly changing **timebase voltage**. The timebase voltage can be selected by a control on the front of the CRO and allows the user to set the time the beam takes to sweep from one side of the screen to the other. This is called the **sweep time** and can vary from microseconds to seconds. The combination of **vertical amplifier gain** and timebase produces a moving spot that perfectly matches the input voltage being tested, with vertical scale divisions representing voltage amplitude and horizontal divisions representing time. Figure 23.2 represents a typical CRO tracing for a constant DC voltage of 12 V as well as a 100 Hz sine wave AC voltage if the timebase is set to one millisecond.

Figure 23.2
CRO tracings.



Some of the common controls on a typical oscilloscope instrument are:

- Intensity and Focus — these controls allow the brightness of the electron beam as well as the spot sharpness to be adjusted on the screen.
- Channels A and B — these are the connector points for the input probes. Each probe usually has a ground clip as well as the test clip, so that the input signal can be measured with respect to the ground or zero potential. On dual-beam or dual-trace oscilloscopes, two separate voltage signals can be connected and displayed on the respective A and B inputs.
- Horizontal and Vertical positions — these controls allow the overall positioning of the spot or trace to be adjusted. For convenience, especially on dual-beam oscilloscopes, two separate voltage waveforms may need to be adjusted horizontally or vertically so that they can be more easily compared. There are separate controls for each channel.
- Volts/div — this stands for volts per 1 cm division in the vertical direction. This is the vertical amplifier gain control and allows the complete input waveform to be displayed no matter what its amplitude might be.
- Sec/div — this stands for seconds per 1 cm division in the horizontal direction. This is the timebase horizontal deflection adjustment. The selector switch will set the time interval representing each horizontal division.
- Trigger level — this setting determines the point at which the beam begins its sweep across the screen. It allows synchronisation of the sweep timebase waveform and the input test waveform so that the signal trace is stable on the screen and does not drift about. The trigger may be either an internal instrument signal or an external signal.
- DC/GND/AC — this selector switch is set to the type of input waveform being measured. For example, if set to AC, any DC component of the input test voltage signal will not cause extra vertical deflection.