Photonics

- Definitions
- Why optical fibres?
- Light emitting diodes
- Light dependent resistors
- A light sensing circuit
- Photodiodes
- Phototransistors
- Remote control circuit
- Digital data
- Binary numbers
- Pulse Code Modulation
- Light modulation
Definitions

• **Photonics** is the area of engineering involving the interactions of light & electronic systems.

• In particular, Photonics forms the basis of modern high-bandwidth communications systems, such as the optical fibre backbone to the NBN or “line of sight” laser based telecommunication systems.

• **Optical transducers** are devices that convert light energy (& information) into an electrical signal or vice versa. These include laser diodes to create light signals & light dependent resistors / photodiodes / phototransistors to convert light signals back into electrical signals.

• In general, higher amounts of data can be transferred by optical systems, although it needs to be converted back into an electronic form to be used.
Why optical fibres?

• Carrying a higher **bandwidth** of data requires a higher frequency signal.

• Higher frequency signals suffer a greater attenuation (loss) in copper wire due to the **skin effect**.

• High frequency signals don’t penetrate through the whole wire cross section, increasing resistance.

• Optical fibre attenuation is only affected by the clarity of the glass used.

• Improved production of the materials has meant that optical fibres now lose only around 5% of the signal intensity per kilometre of length.

• A single optical fibre has the capacity to carry over 1000 telephone conversations - this is ever increasing as technology evolves.
Light emitting diodes

- **Light emitting diodes** are based on semiconductor materials.
- Electrons moving across the PN junction will give off a photon of visible light as they fill in holes in the positively charged P region.
- LED efficiency is continuing to develop at an exponential rate as technologies improve. (Doubling every 18 - 24 months!)
- White light LEDs combine different materials to produce red, green & blue.
- **Laser diodes** emit a very small range of wavelengths. Often they are combined with a built-in photosensor to maintain constant output intensity.
Light dependent resistors

- An LDR is made from a material that decreases resistance as the amount of falling on it increases.
- Photons of light absorbed move electrons in the semi-conductor material to higher energy states (closer to ionisation).
- This means that less electrical energy is lost in the material, as these electrons are already closer to being ionised and conducting.

A common use of the LDR is to trigger a light to come on as the background light intensity falls.
A light sensing circuit

- A common use of the LDR is to trigger a light to come on as the ambient light falls.

1. As the light level falls, resistance of the LDR increases.

2. This increases the potential across the LDR (voltage divider) & increases current into the base of the transistor.

3. Increasing the base current into the transistor makes it more conductive and a larger current is drawn from the collector.

4. The LED light gets brighter.
How do you change the trigger intensity of the light sensor?

1. The fixed resistor & LDR act as a voltage divider into the base of the transistor.

2. Increasing the value of the fixed resistor (47kΩ in this circuit) will drop the potential at the point between the two resistors.

3. The LDR needs to have a higher resistance to achieve the original potential difference.

4. Increasing the fixed resistor means the LDR must be darker to trigger.
Photodiodes conduct in proportion to the amount of incoming light.

In forward bias, photodiodes can act in photovoltaic mode, producing a potential difference across the terminals of around 0.6V under bright light.

A photodiode is a diode can be easily “broken down” in reverse bias (photoconductive mode) by photons of light knocking out electrons from the semiconductor.

This causes the electron / hole pairs to move through the structure if a potential difference is applied (current).

Photodiodes have a very fast response time & are used to respond rapid variations in light intensity.
Photodiodes

Photocurrent (mA)

Potential difference (V)

Dark current

Increasing light intensity

Photovoltaic mode

Photoconductive mode
Phototransistors

• A phototransistor allows for the detection of very low light intensity.

• The base current to the transistor is generated by the absorption of photons of light.

• Increased base current reduces the resistance through the collector / emitter branch and allows more current to flow.

• Current variations are amplified through the main collector - emitter path.
Remote control circuit

- An infra-red LED (on the bottom here) acts to send signals when the switch is closed.
- The phototransistor (on the top here) acts to receive infra-red radiation.
- The brightness of the LED is dependent on the light intensity.
Remote control circuit

• Remote controls send pulses of infra-red light to the sensor.
• The pulses are a series of binary numbers that represent different commands.
Remote control circuit

Increased (infra-red) light makes photo transistor more conductive.

LED turns on with signal.
Digital data

• Analogue signals need to be converted into digital Os and 1s to be transferred by an optical system.

• Pulse code modulation (PCM) can be used to break up a continuous signal into a finite number of divisions at a regular time interval (frequency).

• Binary numbers are a series of Os and 1s that can be used to present any natural number or 0.
Binary numbers

- Binary numbers are a series of Os and 1s (lows & highs) that can be used to represent any natural number or 0.
- Binary numbers are based on adding the powers of two required.
- A 4 bit counter can represent 16 \( (2^4) \) values: from 0 to 15.

\[
14 = 8 + 4 + 2
\]
\[
14 = \text{1} \times 8 + \text{1} \times 4 + \text{1} \times 2 + \text{0} \times 1
\]
\[
14 = 1110
\]
4 bit encoding allows 16 values of intensity.
(CD audio uses 16 bit: 65,536 values)

15 Hz sampling records data 15 times per second.
(CD audio uses 44.1 kHz)

4 bit sampled at 15 Hz would require approximately 60 bits / second bandwidth.
(CD audio uses around 1.4 Mb / sec for two channels)
Light modulation

- **Modulation** is defined as the addition of information to a carrier signal, such as radio waves or electric current.

- Digital modulation refers to converting an analogue signal into a digital signal.

- Optical systems use changes in the intensity of light signals to convey data.

- Modulation occurs when digital electric signals are converted into light signals by a laser diode.

- **Demodulation** occurs when the light signal is converted into an electric signal by a photodiode.