Analog Electronics

DIPLOMA WALLAH

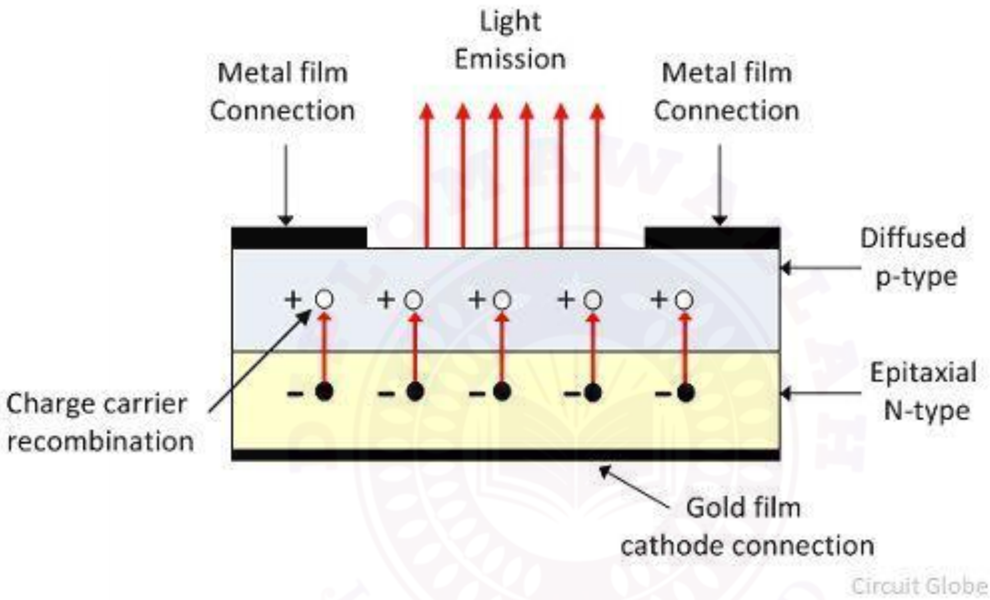
EE/EEE

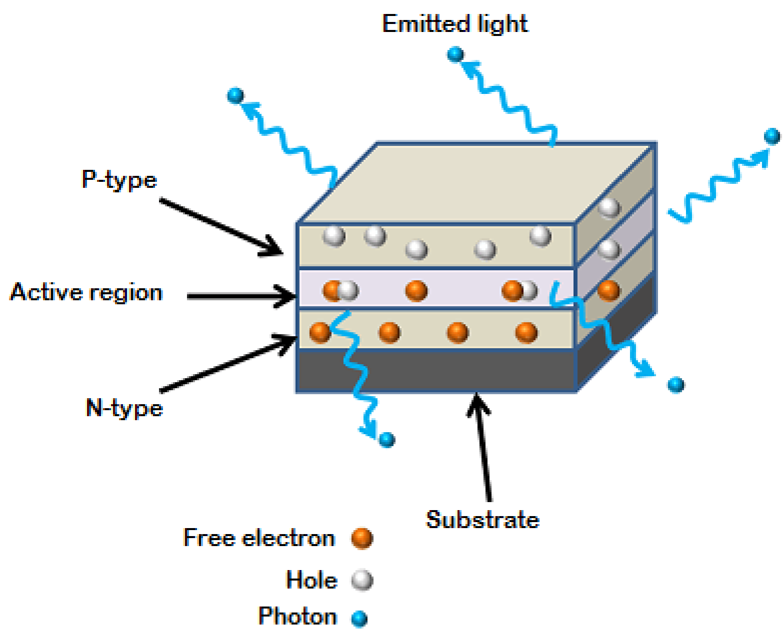
Jharkhand University Of Technology (JUT)

Unit 05

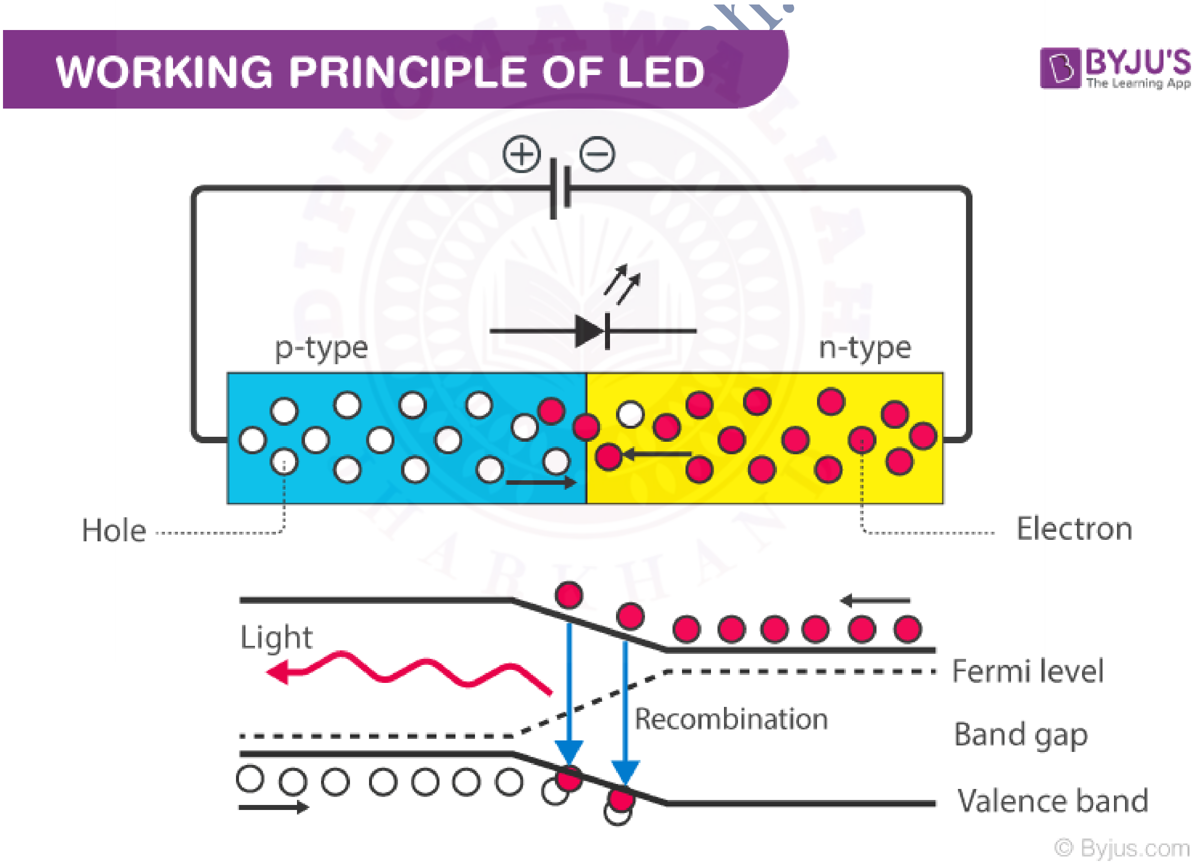
A. Opto-Electronic Devices & Opto-Couplers

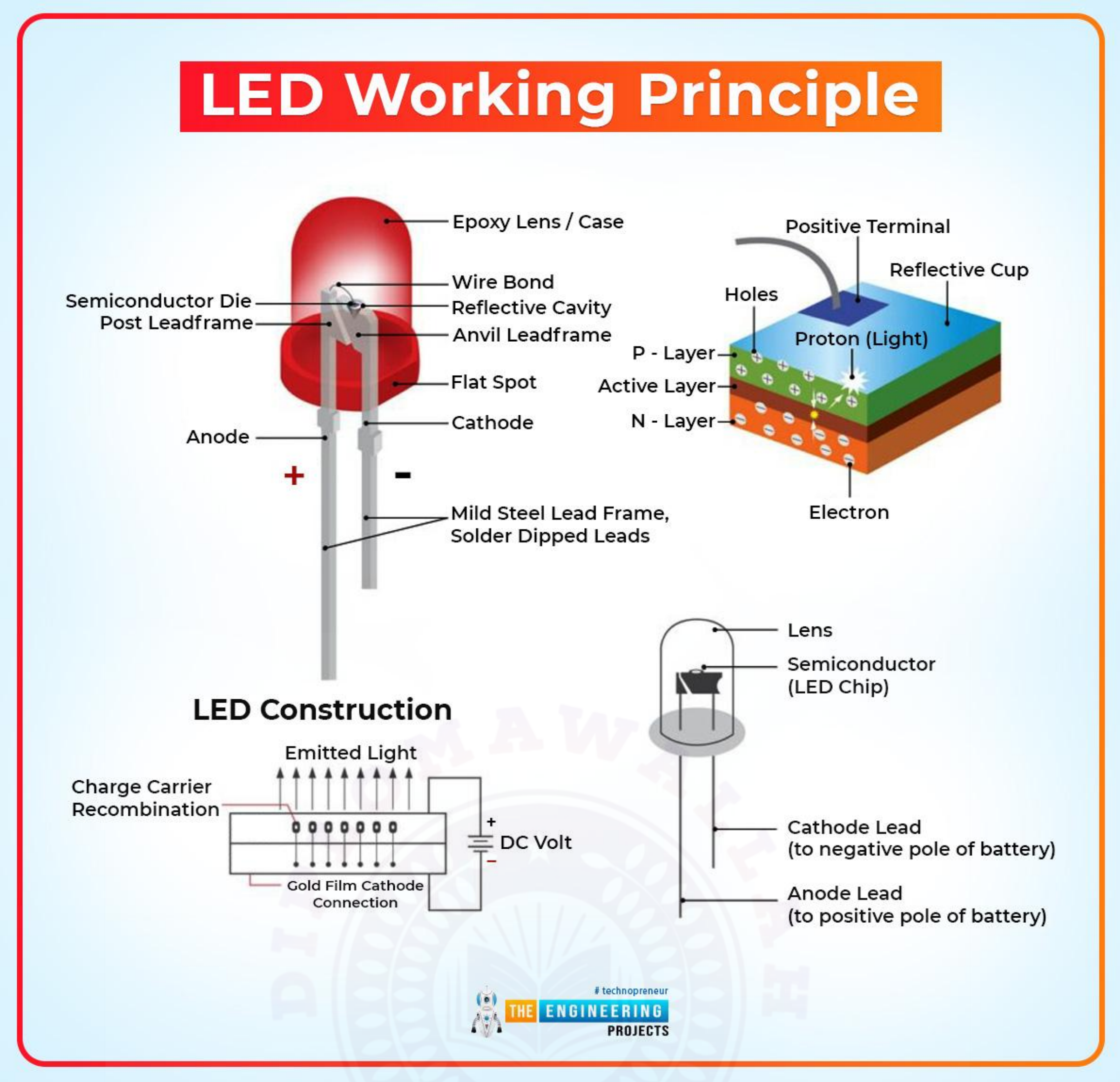
A1. Light-Emitting Diode (LED) & IR LED





Construction of LED




LED Working Principle
Epoxy Lens / Case
Wire Bond
Reflective Cavity
Anvil Leadframe
Flat Spot
Cathode
Semiconductor Die
Post Leadframe
Anode
+
-
Mild Steel Lead Frame,
Solder Dipped Leads
LED Construction
Positive Terminal
Reflective Cup
Holes
Proton (Light)
P - Layer
Active Layer
N - Layer
Electron
Lens
Semiconductor
(LED Chip)
Cathode Lead
(to negative pole of battery)
Anode Lead
(to positive pole of battery)
Emitted Light
Charge Carrier
Recombination
DC Volt
Gold Film Cathode
Connection
technopreneur
THE ENGINEERING
PROJECTS

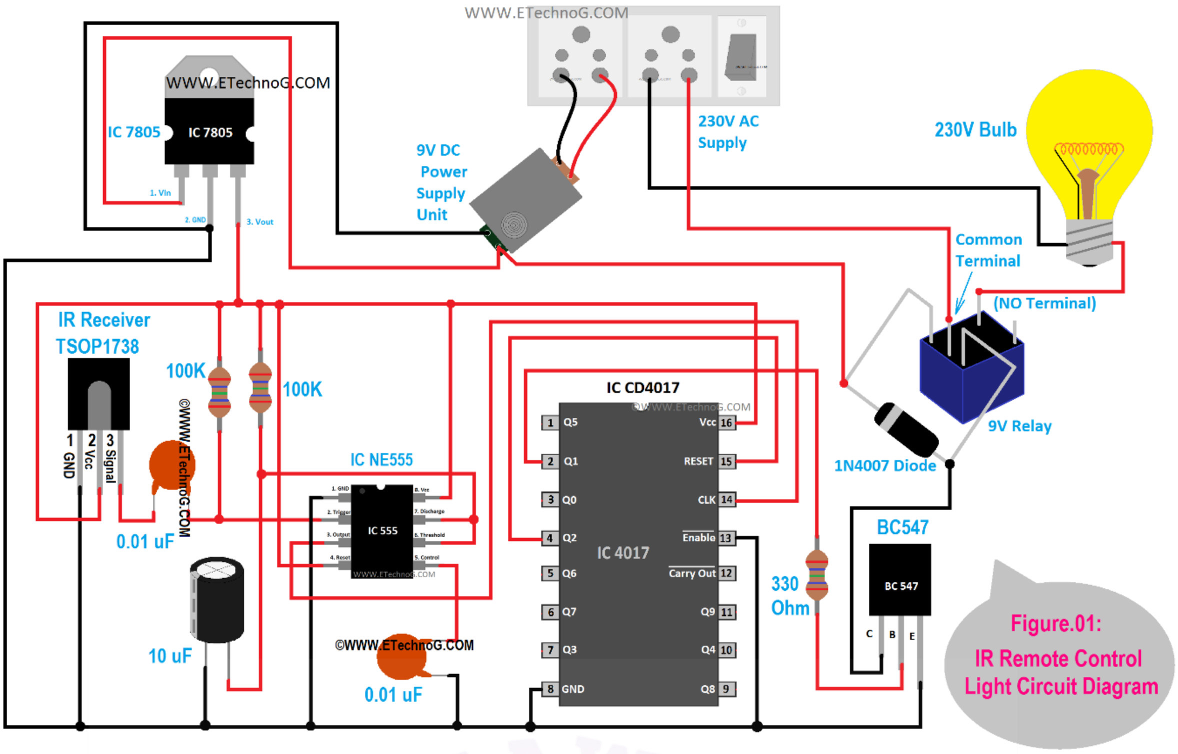
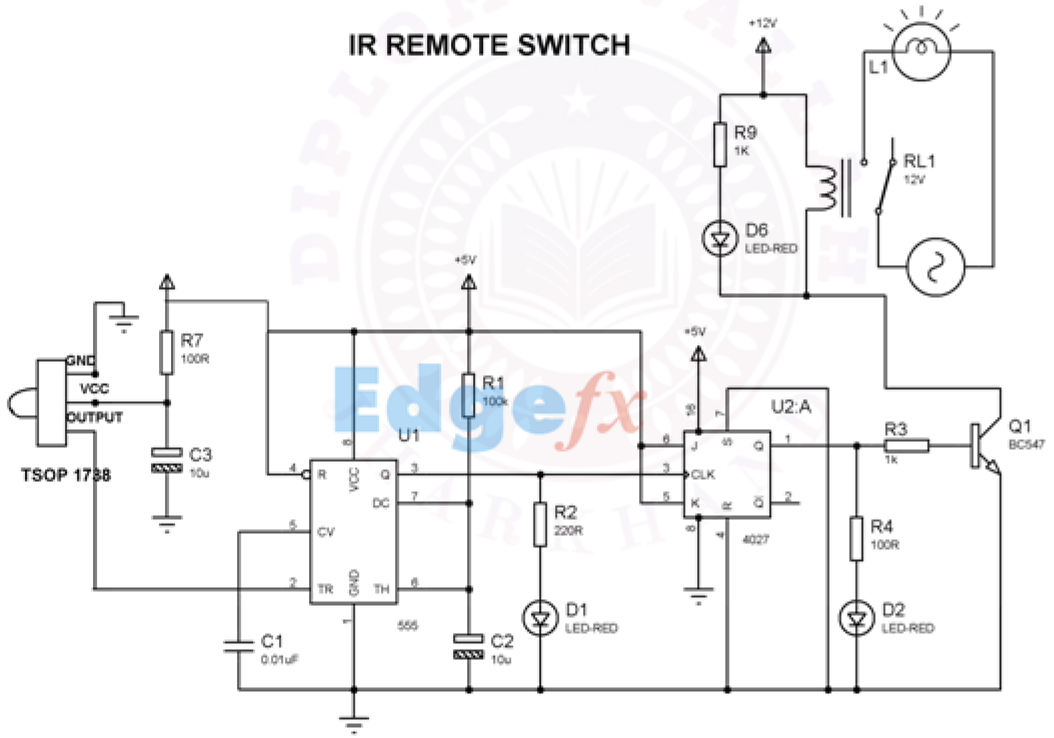


Figure.01: IR Remote Control Light Circuit Diagram



Construction & Materials

- An LED is basically a p-n junction diode made of compound semiconductor materials such as GaAs (gallium arsenide), GaP (gallium phosphide), AlGaInP etc. (Electrical 4U)

- The LED die (junction) is encapsulated in epoxy resin (which often acts as a lens) and the leads are anode (+) and cathode (−).
- IR LED is similar construction but emits in the infrared spectrum rather than visible light – used in remote controls, IR communication, sensing.

Working Principle

- The working is based on *electroluminescence*. When the LED is forward-biased (anode positive with respect to cathode) electrons from the n-region and holes from the p-region recombine in the depletion/active region. When they recombine, energy is released as photons (light) rather than just heat. (Electrical 4U)
- The wavelength (colour) of light depends on the band-gap of the semiconductor material used: the larger the band-gap, the shorter the wavelength (towards blue/UV). (Wikipedia)
- For an IR LED, the emission is invisible to human eye but used for sensors, remote controls etc.

Characteristics

- Forward voltage (V_F): the voltage required to forward-bias the LED. E.g., red ~1.8–2.2 V, blue/white ~3–3.6 V.
- Forward current (I_F): maximum continuous current (often ~10–30 mA for indicator LEDs, higher for high-power LEDs). Must not exceed, else damage. (Basic Electronics Tutorials)
- Efficiency: Ratio of light output to electrical input energy (LEDs are much more efficient than incandescent bulbs because less heat wasted). (The Department of Energy's Energy.gov)
- Lifetime: Solid-state device, durable, shock resistant.
- Polarity matters: Anode/cathode must be correct – an LED only emits light when correctly forward-biased.

Applications

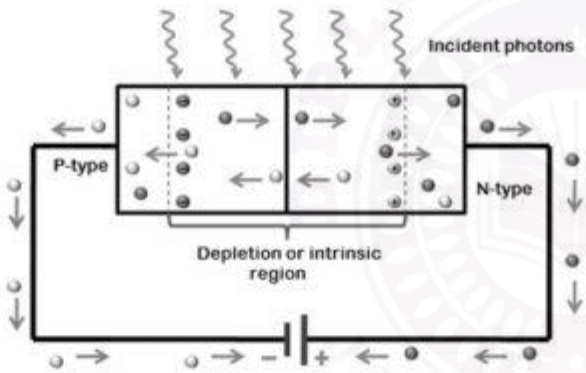
- Indicator lights, displays (seven-segment, dot-matrix), back-lighting.
- IR LED: remote controls, IR remote sensors, optical communication.

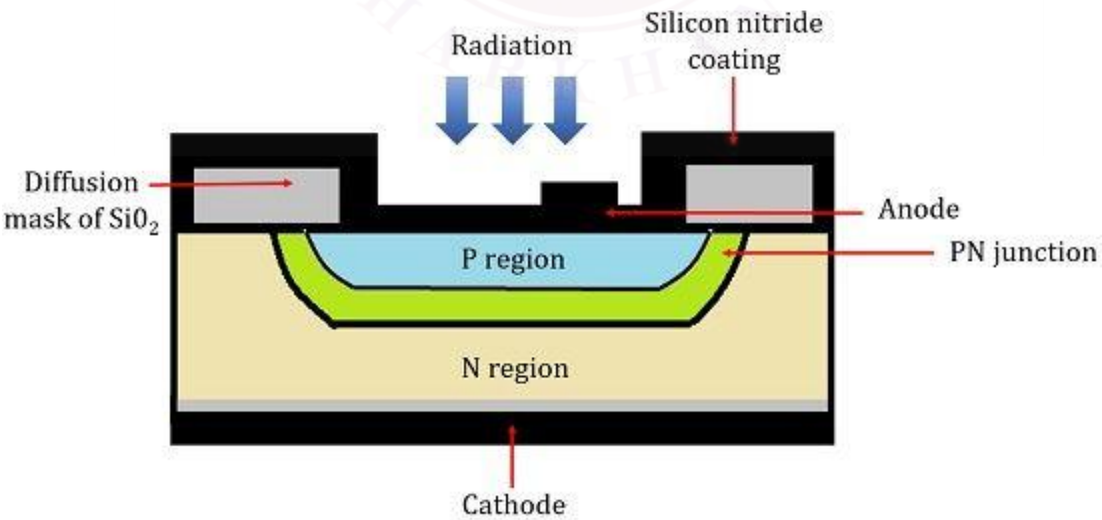
- Lighting: high-power LEDs for lighting, automotive headlamps.
- Fibre-optics, signalling, visual displays.

Design Tips

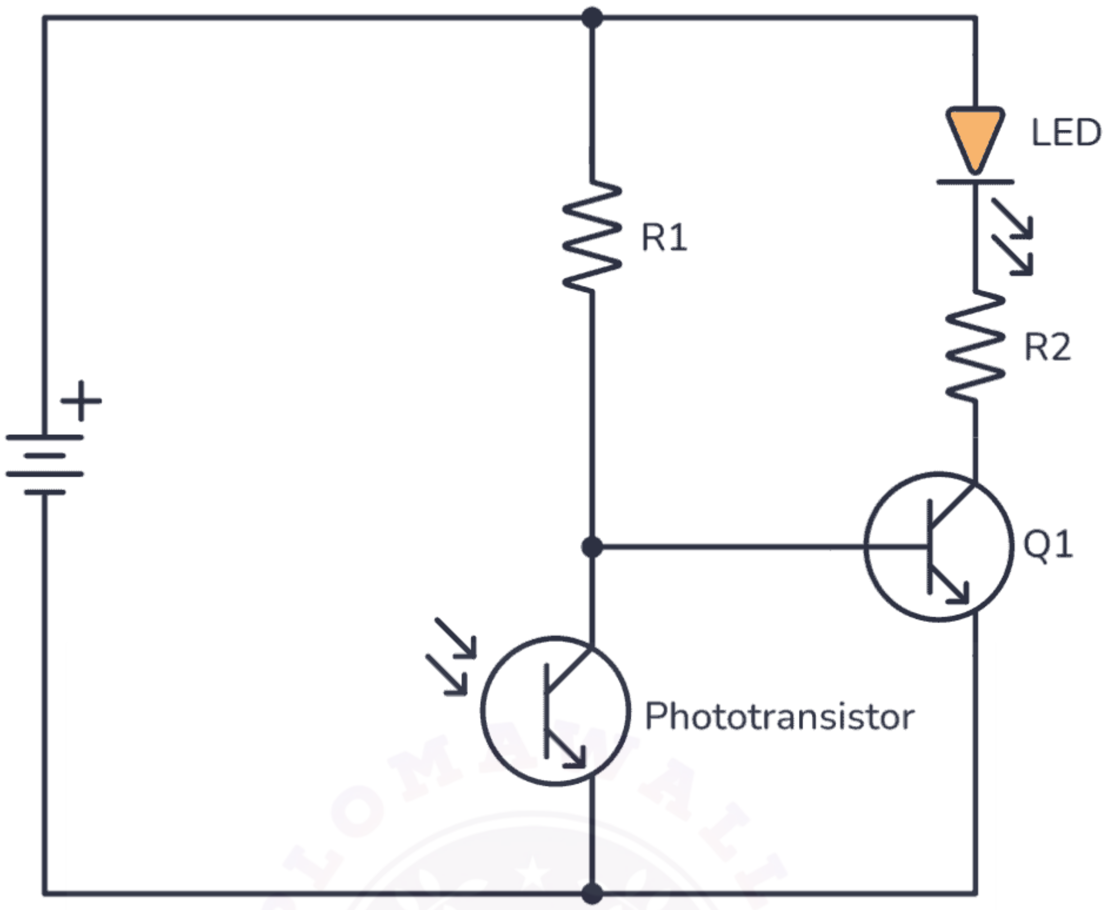
- Always use a **series resistor** to limit current:
  [
  R = \frac{V_{supply} - V_F}{I_F}
  ]
  where (V_F) is forward voltage, (I_F) desired current. (Basic Electronics Tutorials)
- Check that the LED's power dissipation and thermal management are adequate (especially high-power types).
- Match emission wavelength (for IR LED) to the detector's sensitivity (photodiode/phototransistor) when designing sensors.

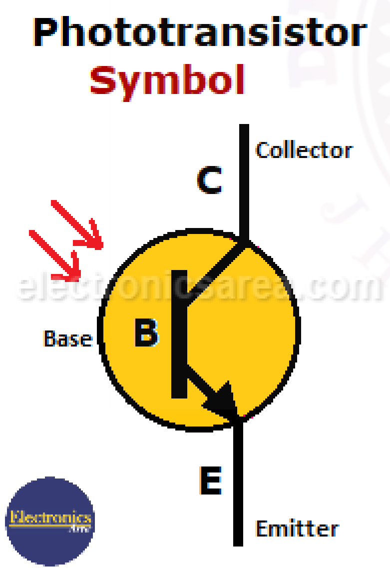
A2. Photodiode & Phototransistor

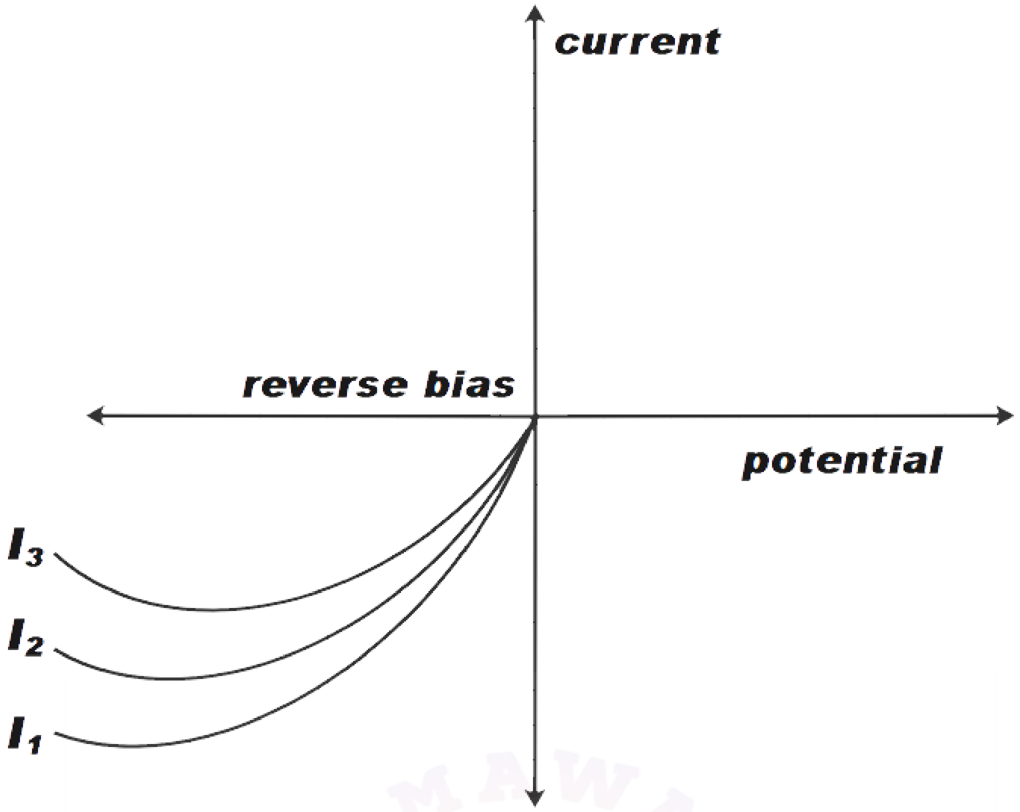


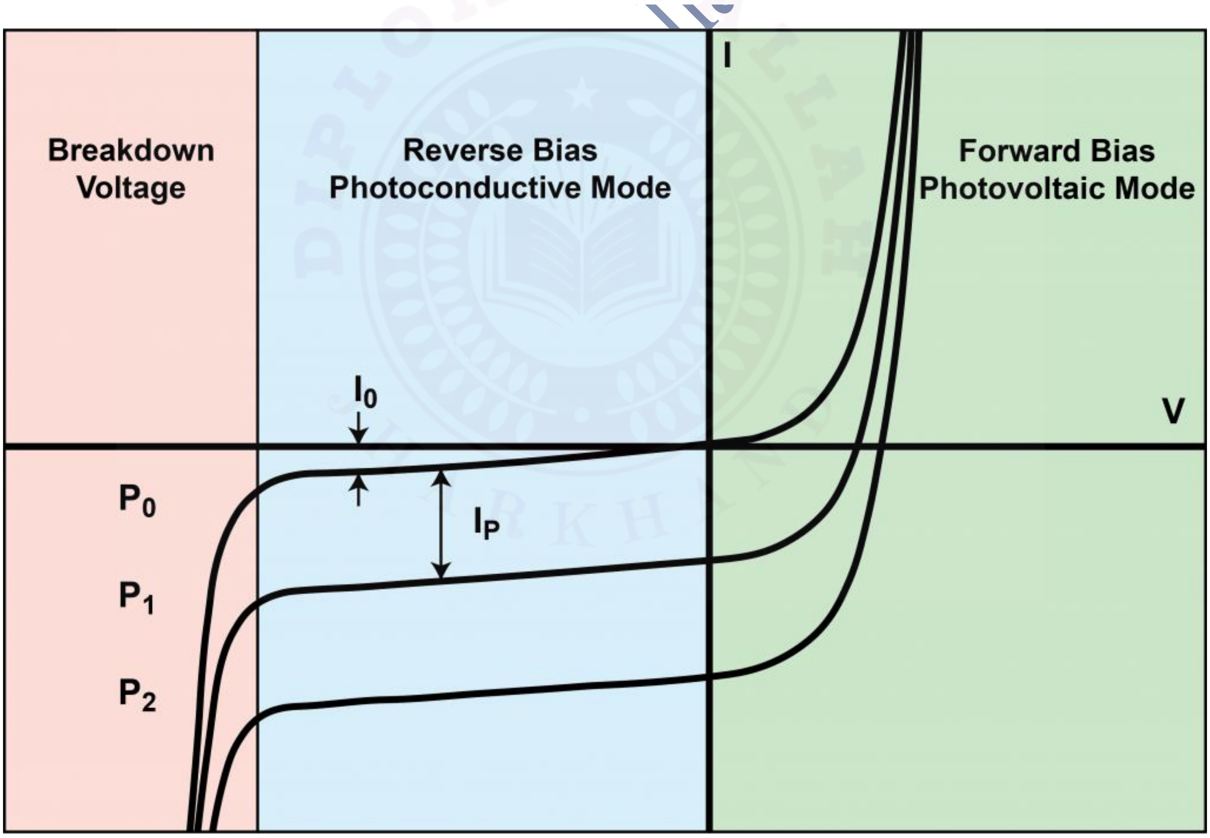


Structure of Photodiode


LED
R1
R2
Q1
Phototransistor


Phototransistor
Symbol
Collector
C
Base
B
E
Emitter





Photodiode

- A photodiode is a p-n or p-i-n semiconductor device whose junction is exposed (or behind a transparent window) so that incident light generates electron-hole pairs in the depletion region. (Homemade Circuits)

- Works commonly in *reverse bias* (photoconductive mode): light increases current under reverse bias; the photocurrent is proportional to incident light intensity.
- Characteristics: responsivity (A/W), dark current (current in absence of light), response time (how fast it responds).
- Applications: light sensors, optical communication receivers, solar cells (large area variant), ambient light sensing.

Phototransistor

- A phototransistor is essentially a transistor whose base is driven by light (rather than by an external base current). The light-induced base current is amplified by transistor action, so the device gives higher gain compared to photodiode. (ORIENT COMPONENTS)
- It is slower in response than photodiode (because of transistor's stored charge), but simpler to interface and gives higher output current.
- Applications: IR remote receivers, light-barrier sensors, opto-coupler internal detectors.

Comparison

Device	Speed	Gain	Output current	Typical use
Photodiode	Very fast	Low (≈1)	Smaller	High-speed detection
Phototransistor	Moderate	High (transistor gain)	Higher	General light sensing

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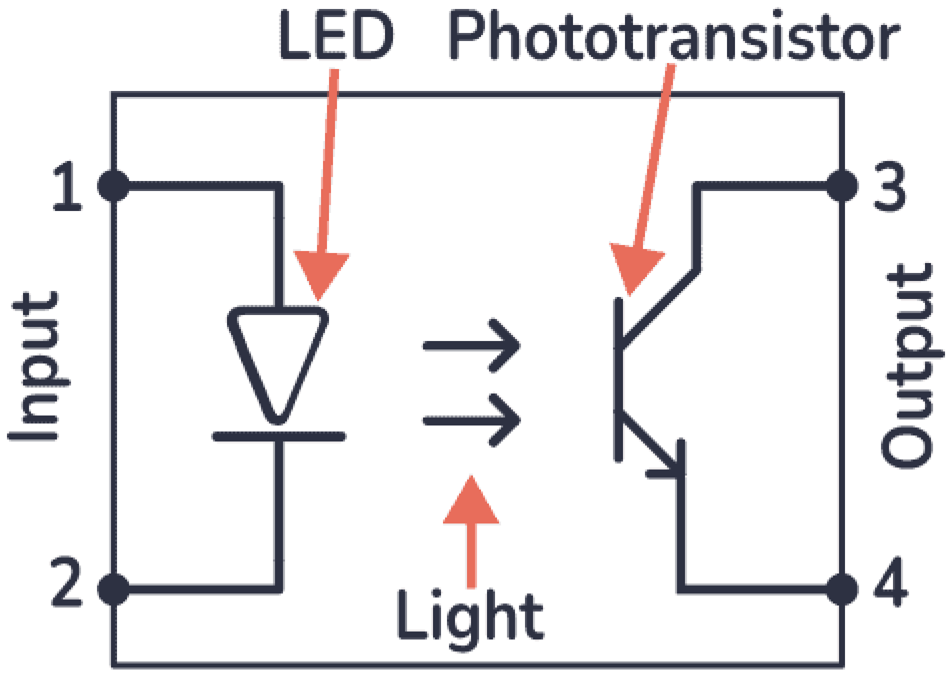
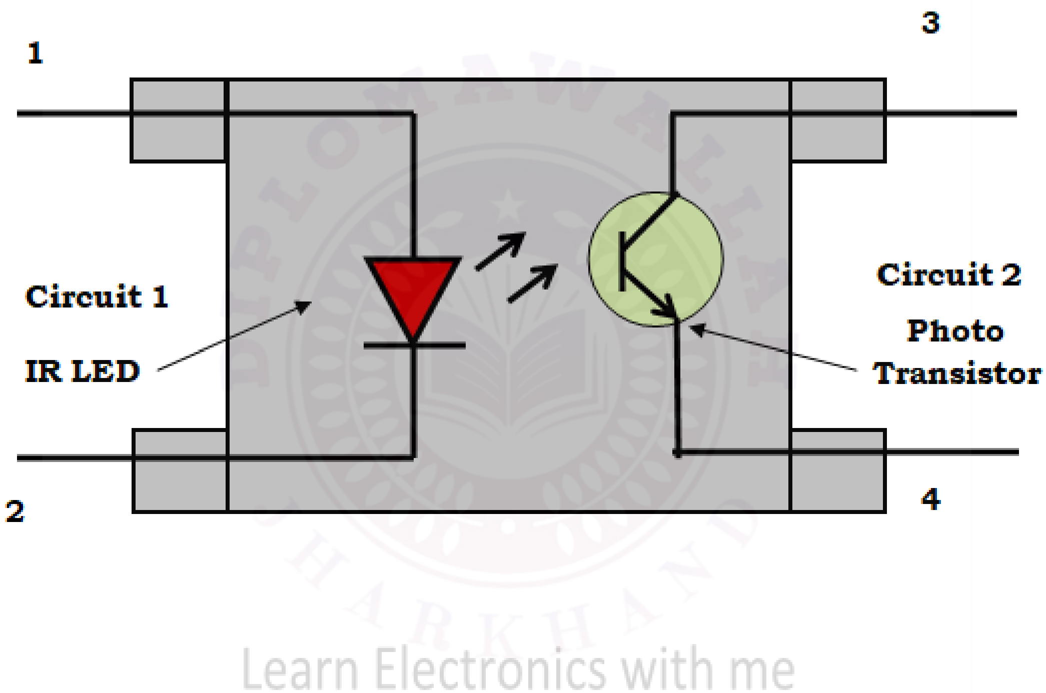
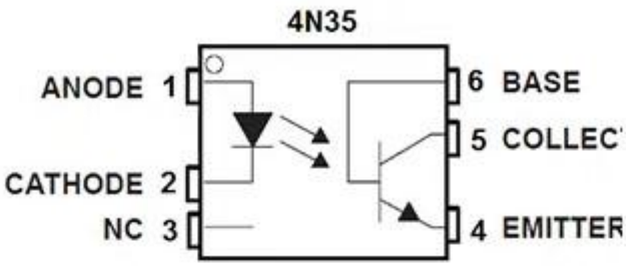
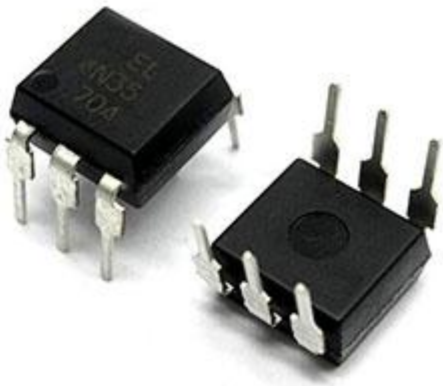
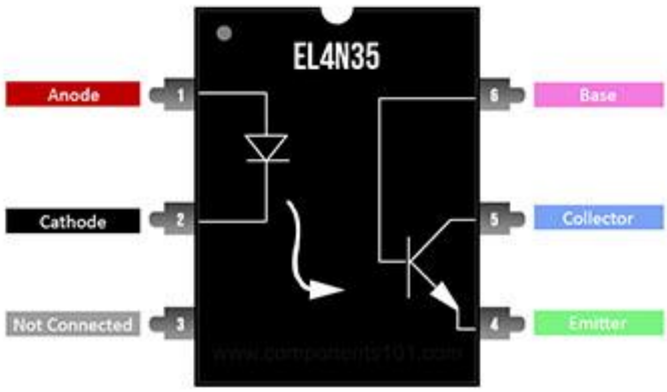
A3. Opto-Couplers (Opto-Isolators)


LED
Phototransistor
1
2
3
4
Input
Output
Light

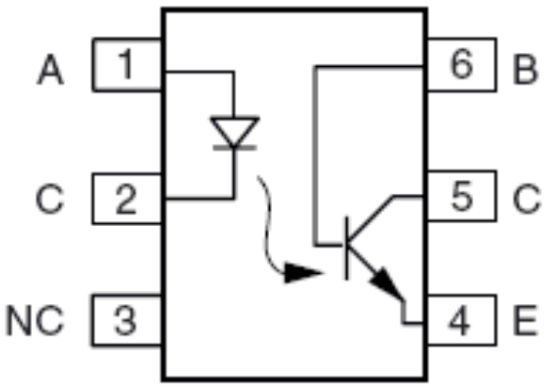

1
2
3
4
Circuit 1
IR LED
Circuit 2
Photo
Transistor
Learn Electronics with me

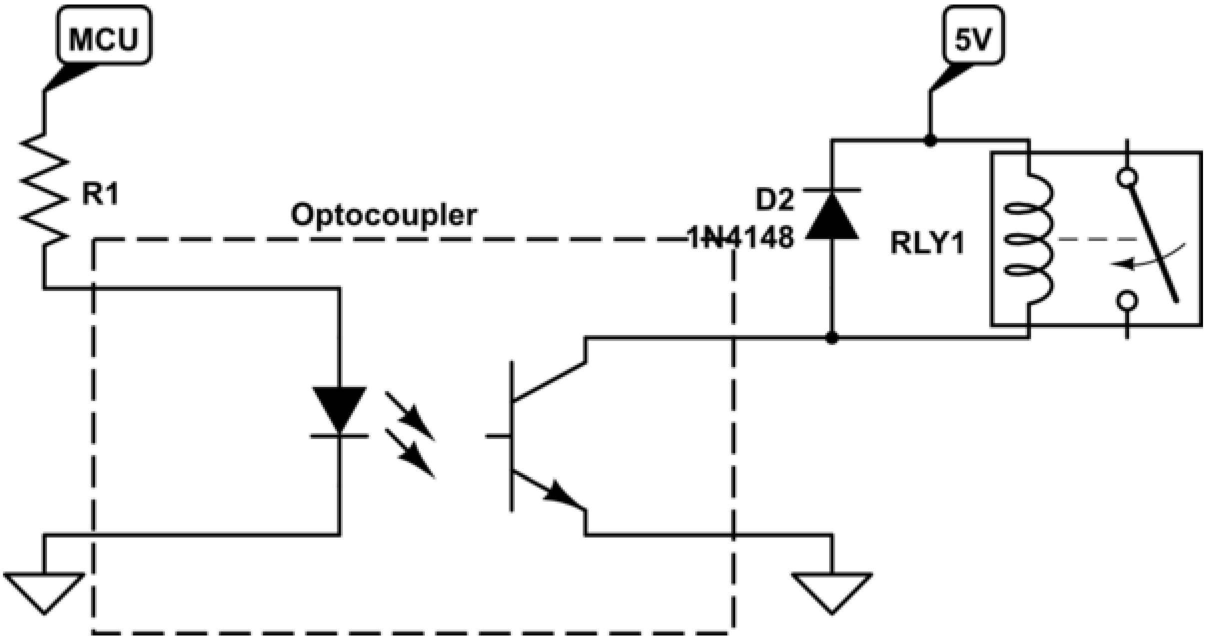


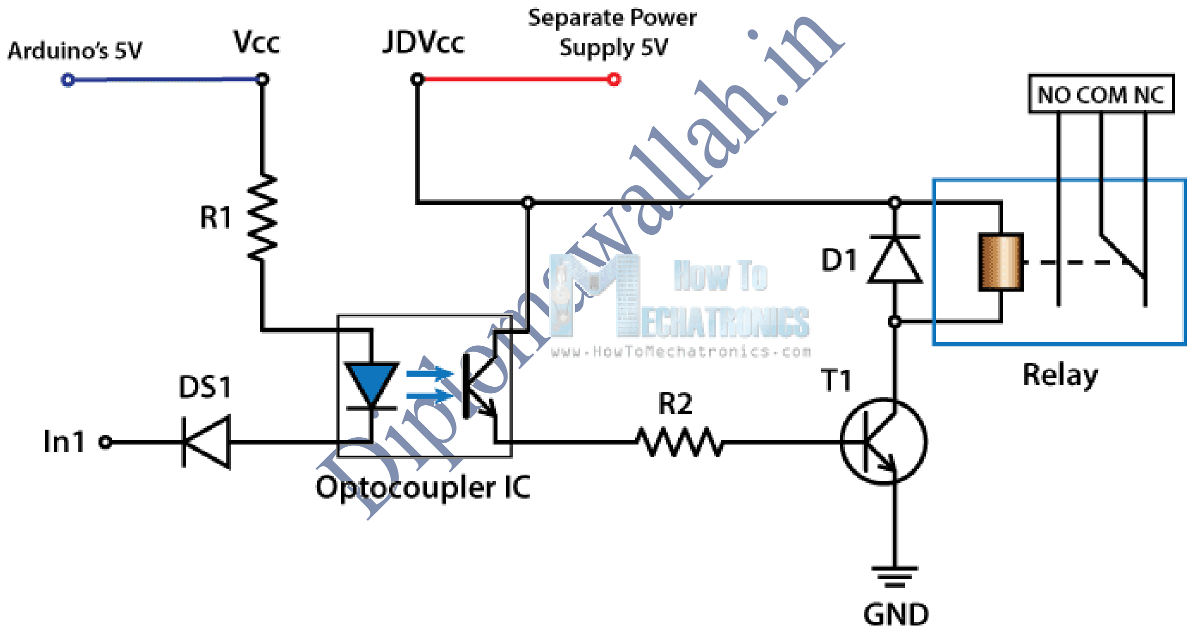




4N35 Optocoupler IC







Definition & Function

- An opto-coupler (also called opto-isolator) is a component that transfers electrical signals between two **electrically isolated** circuits using light as the coupling medium. It typically has an LED on the input side and a photodiode or phototransistor (or photo-SCR/triac) on the output side, all enclosed in a single package. (Basic Electronics Tutorials)
- Because there is no direct electrical connection, opto-couplers provide galvanic isolation; important in protecting low-voltage logic from high-voltage mains, noise, ground loops.

Working

- When the LED is driven by input signal, it emits light. That light falls on the detector (phototransistor or photodiode) causing current to flow in the output circuit.
- As the light is blocked/absent, output side stops conducting; thus the signal is transferred while the two sides remain isolated. (Inst Tools)
- Key parameter: CTR (Current Transfer Ratio) = output detector current / input LED current (typically expressed as a percentage). Also, turn-on/turn-off times, isolation voltage, input/output voltage limits.

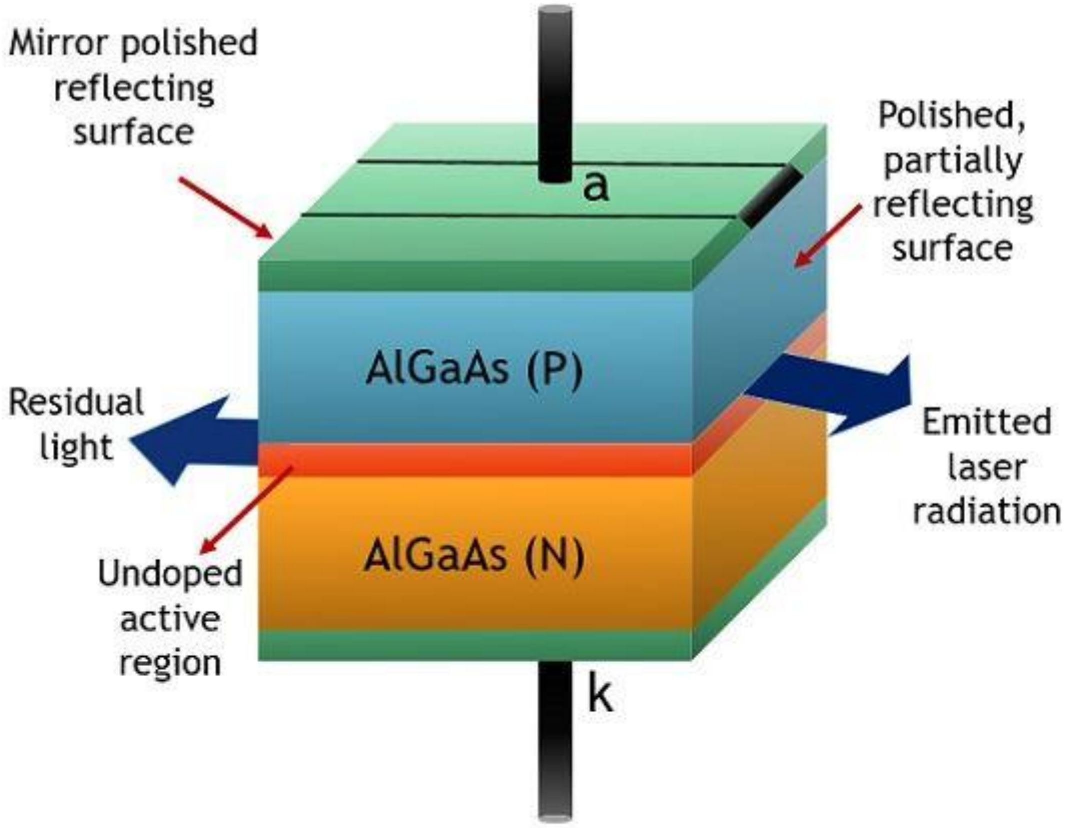
Applications

- Isolating microcontroller or digital logic from high-voltage switch circuits or noisy power electronics.
- Telecommunication interfaces, PLCs, power supply feedback, motor drive feedback circuits.
- Isolated signal transfer in medical electronics (safety-critical), industrial instrumentation.

Design Considerations

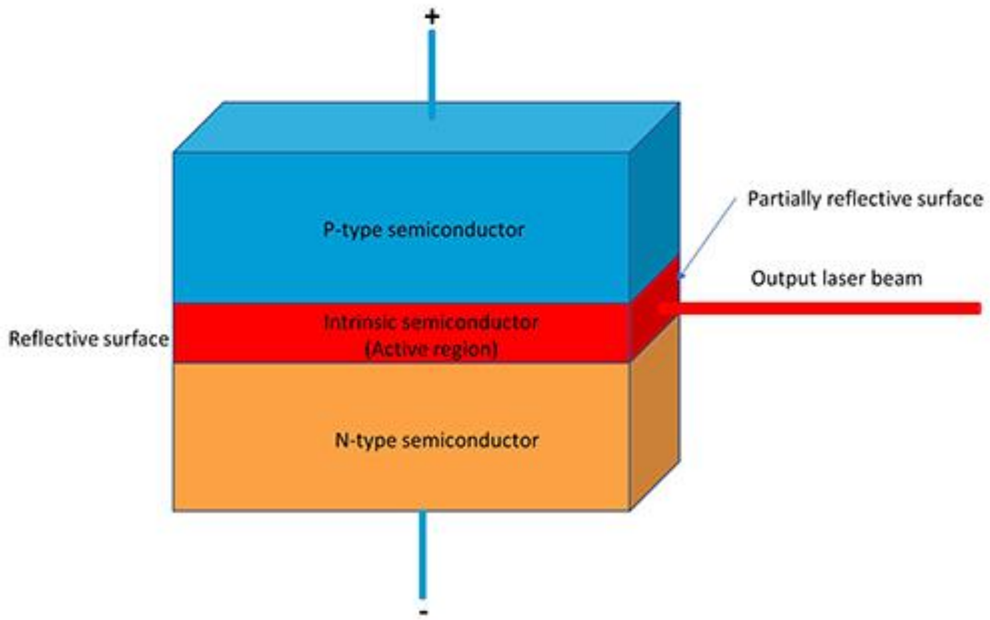
- Ensure LED drive current is sufficient to get required detector current (based on CTR).
- Check maximum isolation voltage rating.
- Check whether detector is photodiode, phototransistor or triac type depending on AC/DC, speed, and current requirements.
- For faster response, choose LED + photodiode type instead of phototransistor.

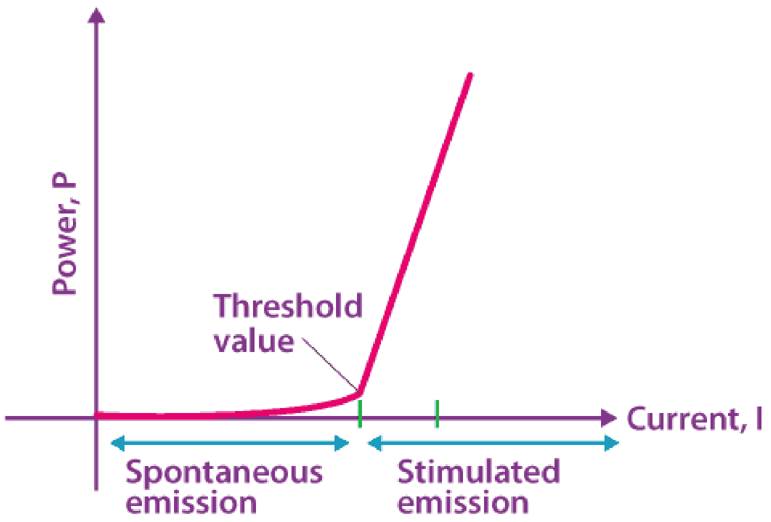
A4. Laser Diodes

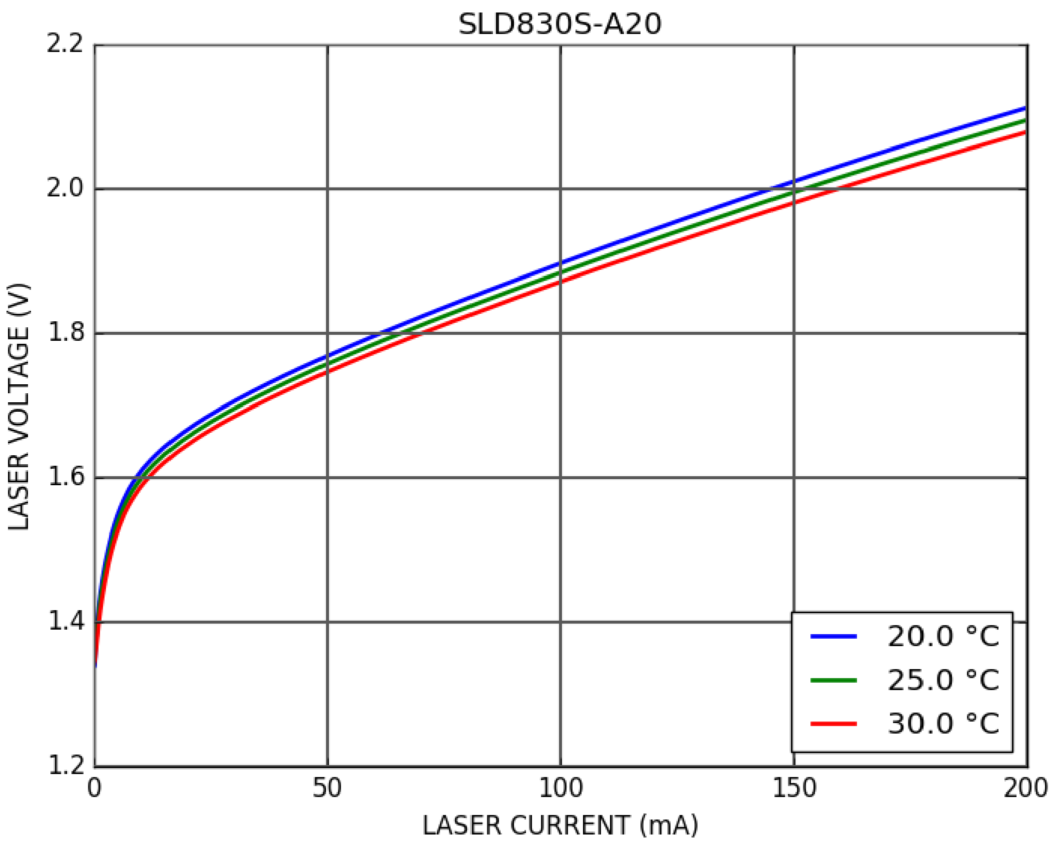


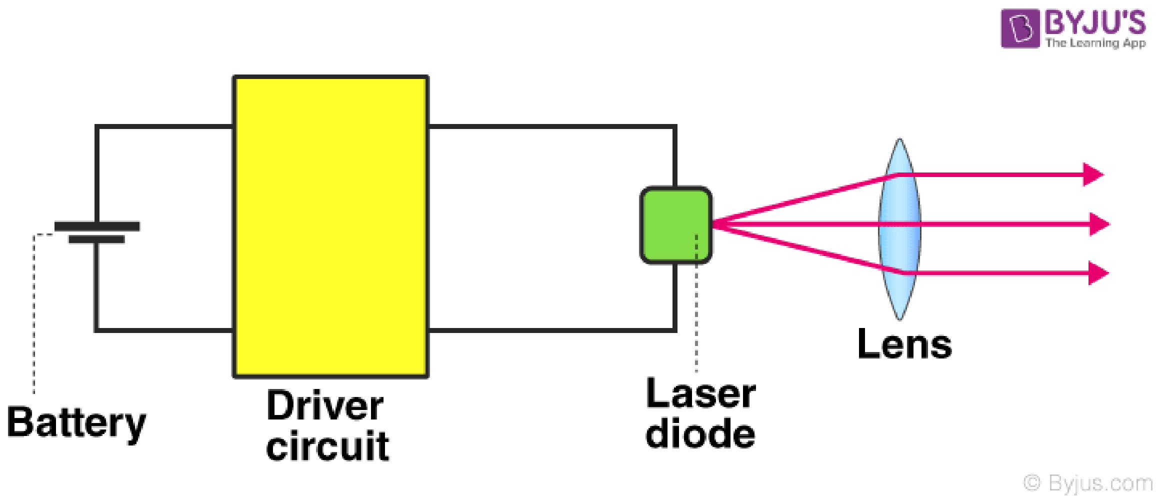
Constructional detail of laser diode

Laser diode structure




Power, P
Threshold value
Current, I
Spontaneous emission
Stimulated emission


SLD830S-A20
LASER VOLTAGE (V)
LASER CURRENT (mA)
2.2
2.0
1.8
1.6
1.4
1.2
0
50
100
150
200
20.0 °C
25.0 °C
30.0 °C



Construction & Principle

- A laser diode is a semiconductor diode designed so that the p-n junction (or p-i-n) region acts as a resonant optical cavity; the ends of the chip act like mirrors, enabling stimulated emission of photons that are coherent (same phase), monochromatic and directional.
- When the driving current exceeds a threshold (I_{\text{th}}), stimulated emission dominates and lasing occurs. Below that current it behaves like an LED (spontaneous emission).

Characteristics

- Threshold current (I_{\text{th}}): minimum current for lasing.
- Slope efficiency: incremental optical power per incremental current above threshold.
- Output wavelength: determined by material and cavity design.
- Narrow beam divergence, coherent output.
- Sensitive to heat: thermal management is critical.

Applications

- Fibre-optics communication, barcode scanners, CD/DVD/Blu-ray players, laser pointers, laser printers, medical surgery lasers, industrial cutting/welding (in higher power diode variants).

- Because laser diodes can modulate at very high frequencies, they're used in high-speed optical links.

Design Tips

- Drive with constant current source (not just constant voltage) because output varies strongly with current and temperature.
- Use proper heat-sink and temperature control (as wavelength and output drift with temperature).
- Use safety precautions (especially with higher power diodes) – laser radiation can damage eyes.

B. Amplifier Topics

B1. Faithful Amplification

- Faithful amplification means the amplifier should reproduce the input signal at its output with **greater amplitude**, but **without distortion**, preserving the waveform shape, frequency, phase (if required).
- To achieve this, the active device (transistor/MOSFET) must be biased so that the input signal amplitude swings around the Q-point without driving the device into cut-off or saturation.
- The bandwidth, linearity, distortion, noise all affect whether amplification is "faithful".
- In exam context, you should emphasise: stable bias, proper load, minimal clipping, minimal distortion, adequate bandwidth.

B2. Classification of Amplifiers

Based on configuration

- Common-emitter (CE), common-base (CB), common-collector (CC) for BJTs. Each has different input/output impedance, phase shift, gain.
- Multi-stage vs single-stage amplifiers.

Based on power/output stage class

- Class A: Conduction angle 360° (device conducts full cycle). Excellent linearity but poor efficiency (≈20-30%).

- Class B: Conduction ~180° each device (two devices typically in push-pull). Higher efficiency (~78.5% theoretical) but risk of crossover distortion. (Testbook)
- Class AB: Conduction between 180° and 360°; compromise between linearity and efficiency.
- Class C: Conduction <180°, used primarily in RF where waveform distortion is acceptable.

Based on frequency

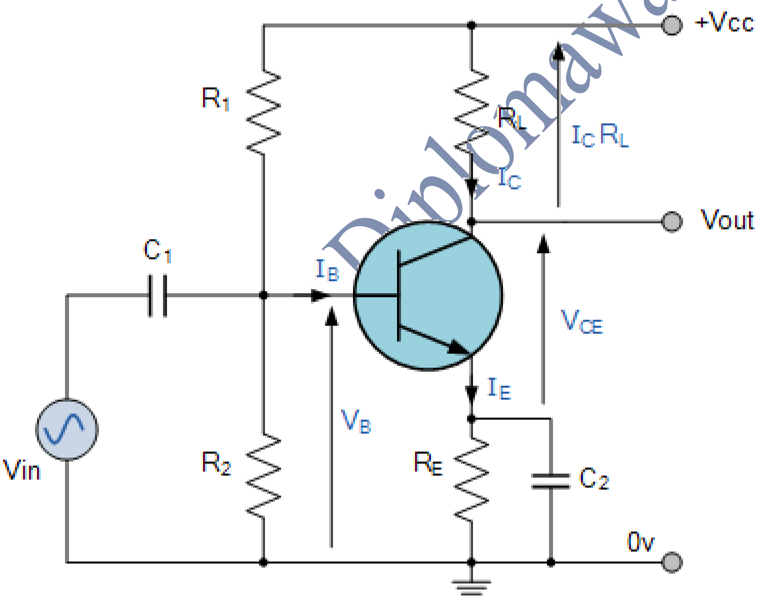
- Audio amplifiers (20 Hz – 20 kHz), video amplifiers (MHz), RF amplifiers (MHz-GHz).

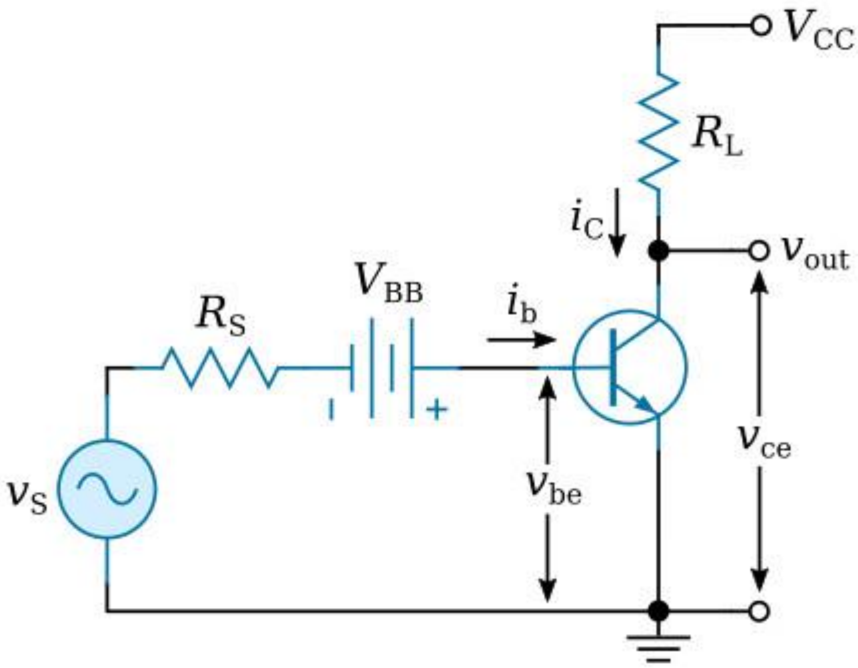
Based on duty / signal

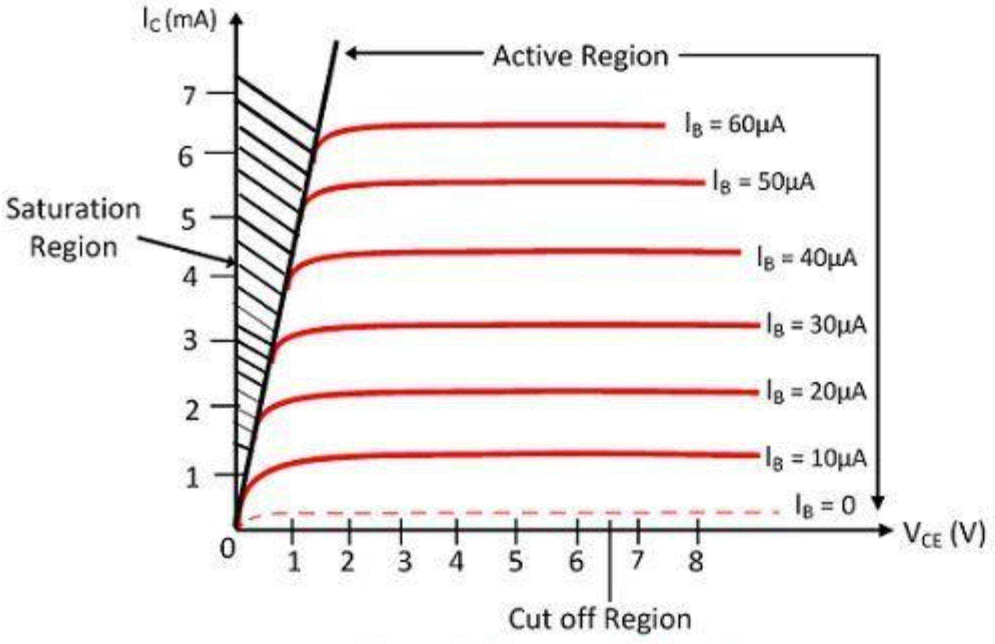
- Small-signal amplifiers vs power amplifiers (which drive loads such as loudspeakers, motors etc).

B3. Transistor Common-Emitter (CE) Amplifier & Push-Pull Amplifier

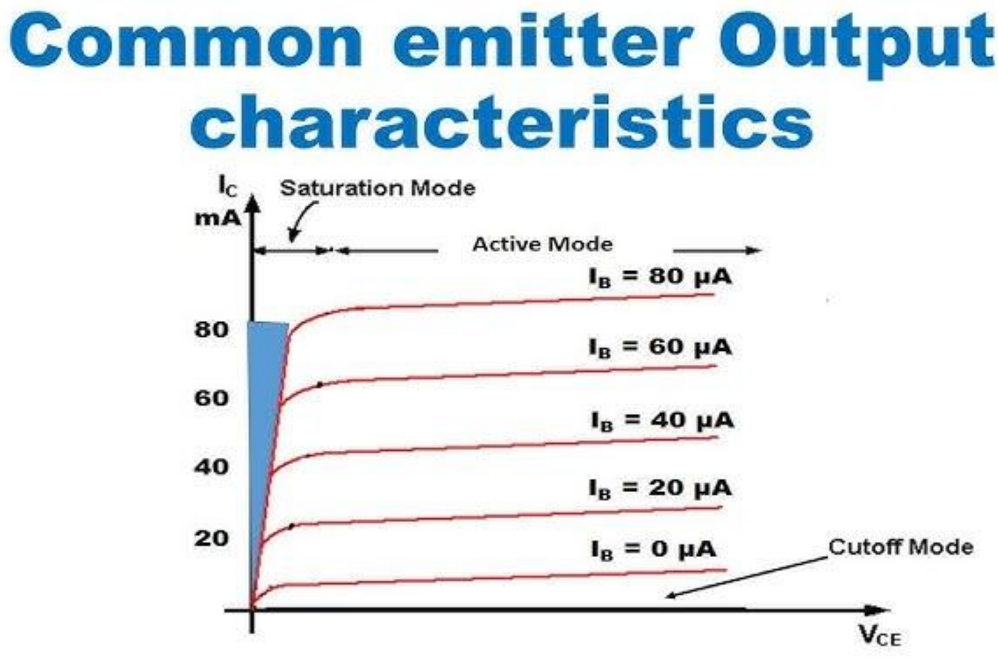
CE Amplifier – Structure & Working







Output Characteristic Curve



- Configuration: Input to base, output from collector, emitter common (usually grounded via emitter resistor for stability).
- Biasing: Use voltage-divider network (R1, R2) to set base voltage, emitter resistor Re for thermal stability, collector resistor Rc as load.
- Operation: With no signal, Q-point is set such that transistor remains in active region. When input signal superimposed on base bias, the collector current varies accordingly; the collector resistor converts that current variation into a larger variation in collector-emitter voltage so we get an amplified signal. The output is typically inverted (i.e., 180° phase shift).
- Key considerations: Ensure input signal amplitude does not drive the transistor into saturation (top of swing) or into cut-off (bottom of swing). The biasing and load line must allow full undistorted swing.
- Formulae (approximate):
  $$A_v \approx -\frac{\beta\, (R_C || R_L)}{r'_e + (1+\beta)R_E}$$
  (assuming emitter resistor partially bypassed etc)
- Applications: audio pre-amplifier stages, intermediate amplifier stages in radios, sensors amplification.

Push-Pull Amplifier – Structure, Working, Advantages

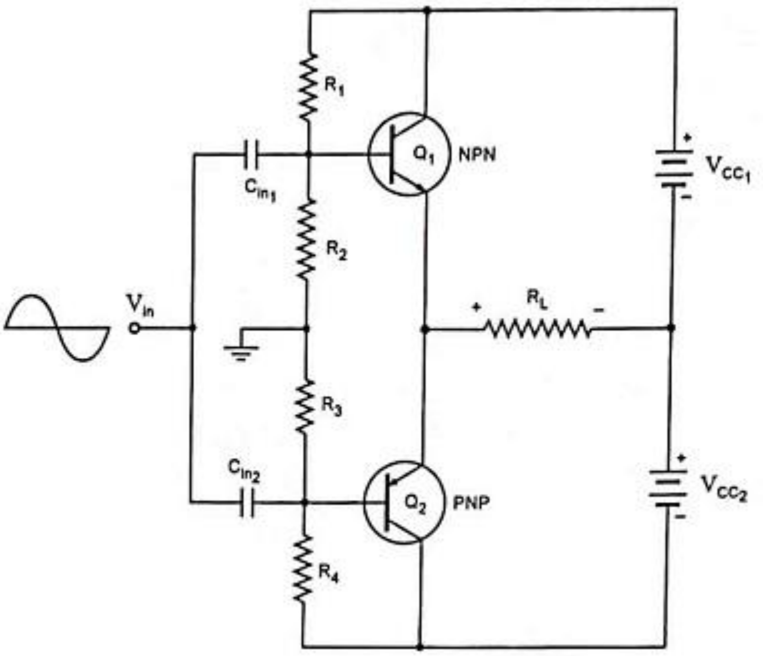
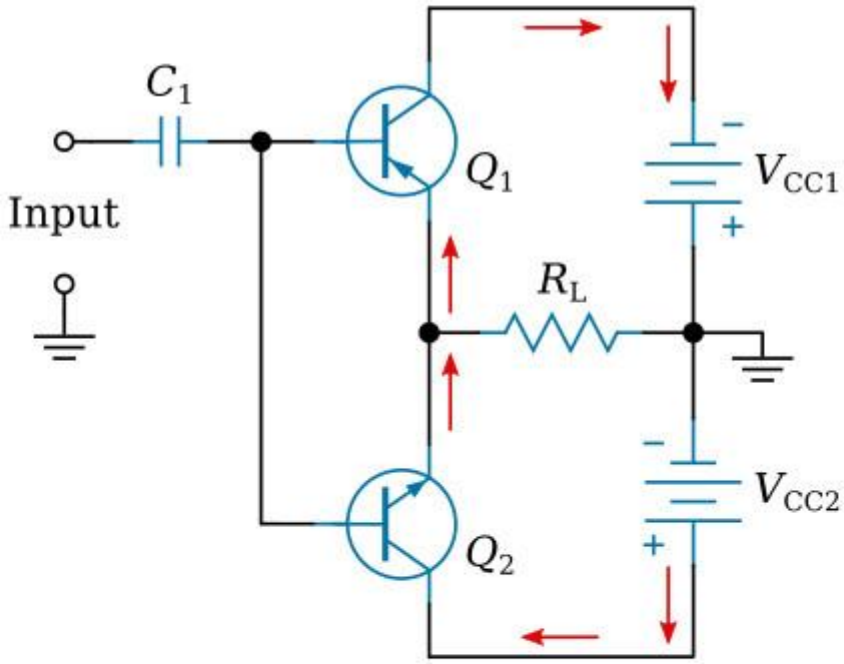
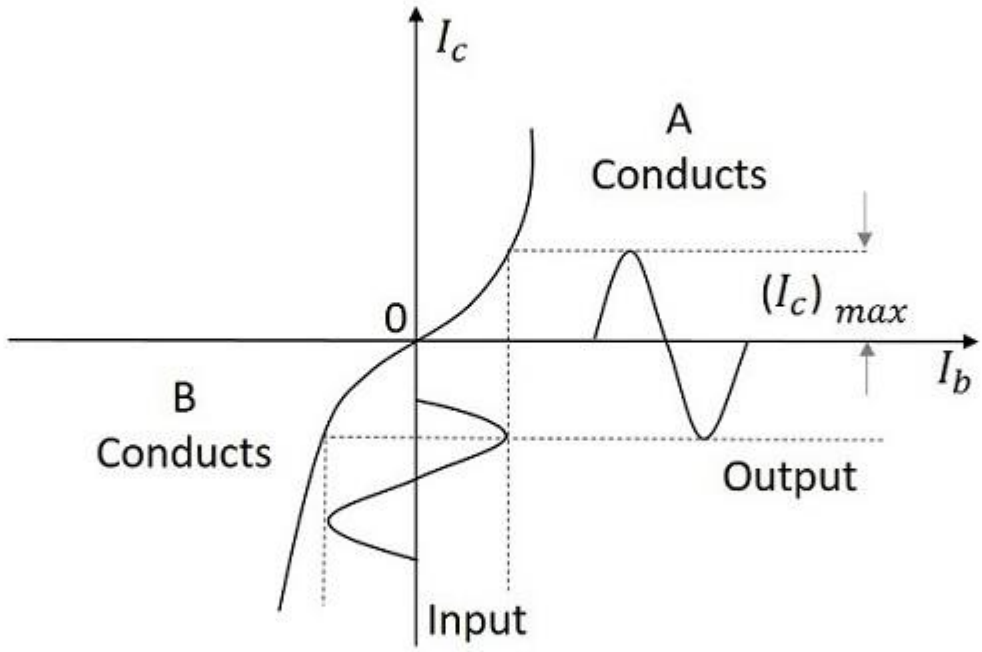


Fig. 17.30 *Complementary Symmetry Push-Pull Class B Power Amplifier*





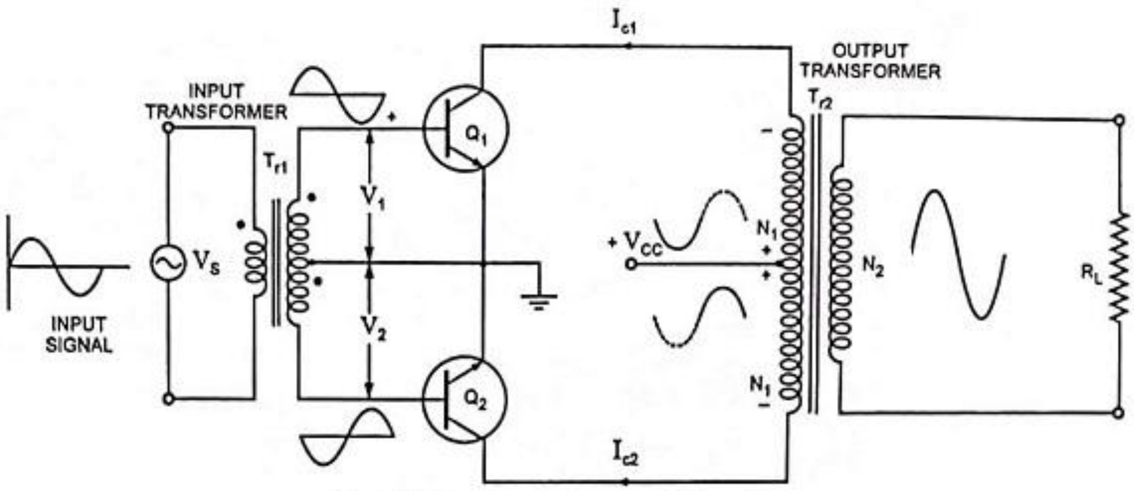


Fig. 17.27 *Class B Push-Pull Amplifier*

- A push-pull amplifier uses two devices (often complementary transistors, one NPN, one PNP) such that one handles the positive half-cycle of the input, the other handles the negative half-cycle. (ElProCus)
- Working: The input signal is split (either by transformer or by phase inverter circuit) into two signals 180° out of phase. One transistor amplifies the positive half, the other amplifies the negative half. The load sees the combination, thus reproducing the

full waveform. This dual-device approach reduces odd distortion and improves efficiency. (4electrical.blogspot.com)

- Efficiency: For ideal class B push-pull, theoretical max efficiency ~78.5%. (Testbook)
- Advantages: Higher efficiency than single-ended class A, less power wastage, output power higher.
- Disadvantages: Crossover distortion (around zero crossing when both devices may be off for a short time). This is mitigated in class AB by biasing devices slightly ON so that conduction overlaps.
- Applications: Audio power amplifiers (driving loudspeakers), power stages in hi-fi, driver stages in power electronics.

Summary

- In opto-electronics: LED/IR LED convert electrical energy → light via electroluminescence; photodiodes/phototransistors convert light → electrical current; opto-couplers use light to transfer signals between isolated circuits; laser diodes generate coherent, narrow beam light for high-speed/precision applications.
- In amplifiers: Faithful amplification requires correct biasing & linear operation; classification by configuration, power class and frequency is essential; CE amplifier is a fundamental small-signal amplifier; push-pull amplifier is a power stage configuration offering higher efficiency and full-wave amplification through complementary devices.

Diploma Wallah

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