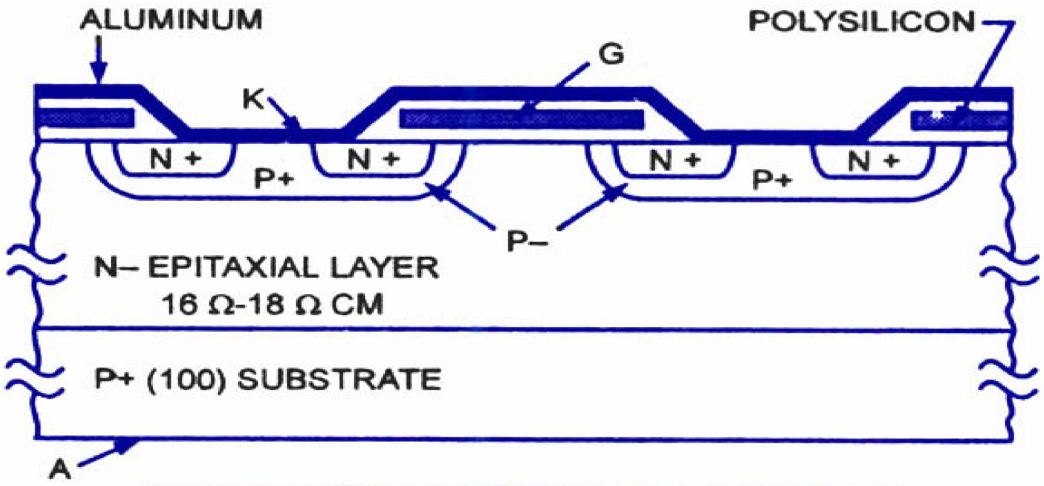
ELECTRONICS DEVICES AND CIRCUITS

IGBTs

IGBT

- ***Insulated gate bipolar transistor*** **(IGBT)** is a new high conductance MOS gate-controlled power switch.



REGION	THICKNESS (μm)
EPI	60 - 62
N^+	1.0 - 1.5
P^-	3.5 - 4.0
P^+	5.0 - 5.5

Structure

IGBT

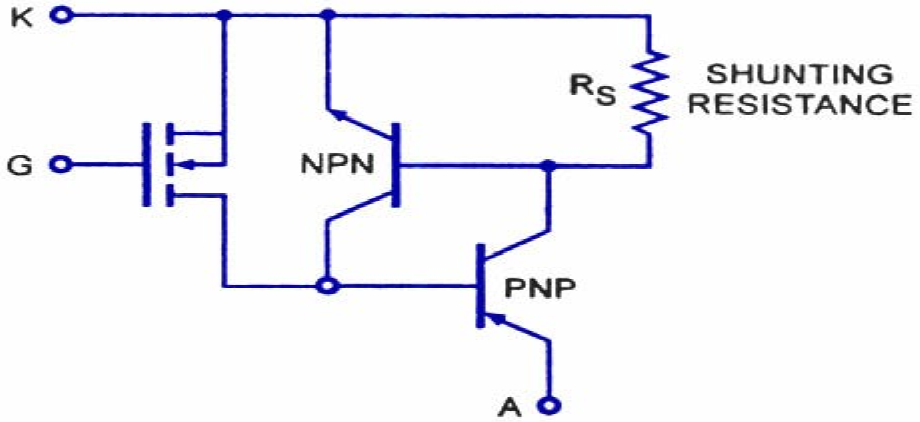
- The fabrication process is similar to that of an N-channel **power MOSFET** but employs an N-epitaxial layer grown on a P+ substrate.
- In operation the epitaxial region is conductivity modulated (by excess holes and electrons) thereby eliminating a major component of the *on-resistance.*
- For example, on-resistance values have been reduced by a factor of about 10 compared with those of conventional N-channel power MOSFET of comparable size and voltage capability.

IGBT

- They are similar to those of an MOS-gated thyristor, except for the presence of the shunting resistance RG in each unit cell.
- The fabrication is like that of a standard N-channel power MOSFET except that the N~ epitaxial silicon layer is grown on a P+ substrate instead of an N+ substrate.
- The heavily doped P+ region in the center of each unit cell, combined with the sintered aluminium contact shorting the N+ and P+ regions, provides the shunting resistance RS shown in IGBT schematics figure.
- This has the effect of lowering the current gain of the N-P-N transistor (αN-P-N) so that αN-P-N + αP-N-P < 1- Thus latching is avoided and gate control is maintained within a large operating range of anode voltage and current.

Device Operation

- The IGBT is a four layer N-P-N-P device with an MOS-gated channel connecting the two N-type regions.



Equivalent Circuit

Insulated Gate Bipolar Transistor (IGBT)

Device Operation

- In the normal mode of operation of an IGBT, a positive voltage is applied to the anode (A) relative to cathode (K).
- When the gate (G) is at zero potential with respect to K, no anode current IA flows for anode voltage VA below the breakdown level VBF.
- When VA < VBF and the gate voltage exceeds the threshold value VGT, electrons pass into the N~-region (base of the P-N-P transistor).
- These electrons lower the potential of the N~-region, forward biasing the P+-N~ (substrate-epi-layer) junction, thereby causing holes to be injected from the P+ substrate into the N- epi-layer region.

Device Operation

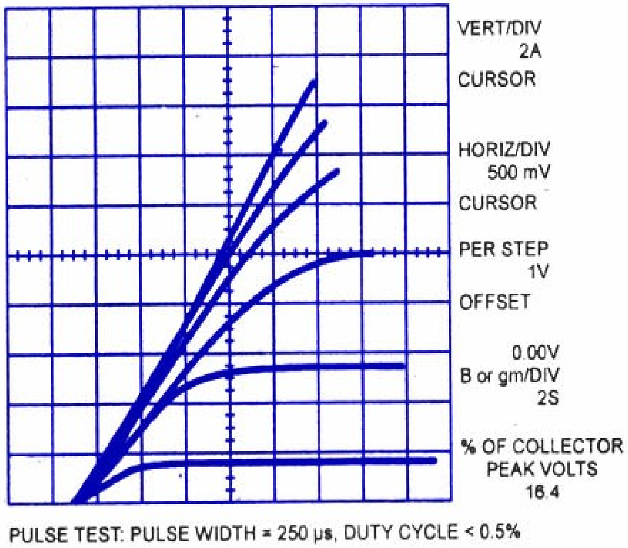
- The excess electrons and holes modulate the conductivity of the high resistivity N-region, which dramatically reduces the on-resistance of the device.
- During normal operation, the shunting, resistor Rg keeps the emitter current of the N-P-N transistor very low, which keeps αN-P-N very low.

Device Operation

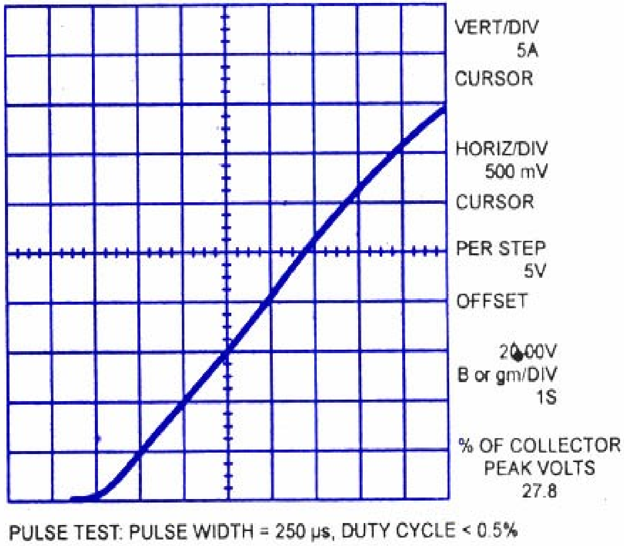
- However, for sufficiently large emitter current IA significant emitter injection may occur in the N-P-N transistor, causing α N-P-N to increase; in this case the four-layer device may latch, accompanied by loss of control by the MOS gate.
- In this event, the device may be turned off by lowering emitter current IA below some holding value, as is typical of a thyristor.
- **This explains how IGBT works** and its mode of operation.

IGBT Characteristics and IGBT specification

- With zero gate bias, the forward characteristic of a IGBT shows very low current (< 1 nA) up to 390 V, where it breaks-up sharply to much larger current levels with only a slight increase in voltage.



MOSFET Like Characteristic



IGBT i -v with $V_G = 20$ *V*

IGBT Characteristics and IGBT specification

- If the internal junction between the P+ substrate and the N~ epitaxial layer had been edge passivated, a similar reverse breakdown characteristic would be expected.
- The actual **reverse breakdown** voltage of the device would be about 100 V if edge passivation is not used.