EEE105 – Summary Sheet – Lectures 15-20

1. Transistors are three terminal devices that can be use in amplifiers or as an electronic switch. A transistor used as a switch is essentially operating as a two state device (on and off), leading to combinations of transistors being used in digital logic circuits.
2. There are two broad types of transistor: the Field Effect Transistor (FET) and the Bipolar Junction Transistor (BJT). There are many sub-types of both these transistor categories.
3. In a FET a channel of a semiconductor material is electronically constricted by a potential applied to the Gate contact. We do not want current flow through the gate contact.
   a. Current in the device flows from the source contact to the drain contact at either end of the channel.
   b. In FETs the channel is non-uniform as the voltage between source and gate, and drain and gate is different.
   c. The channel is normally thinner at the drain end. If the drain voltage is large enough the channel becomes extremely thin at the drain end. This is called the pinch-off condition)
   d. When the channel is pinched off the drain current becomes independent of the drain voltage.
4. In a Junction FET (JFET) the channel constriction is made using the depletion region of a reverse biased p-n junction.
   a. Increasing the reverse bias reduces the channel thickness and increases the resistance of the channel
   b. The ***saturation*** current that flows through the JFET when it is pinched off will decrease with increasing gate voltage.
5. It can be shown that for a device with low drain voltage, the drain current can be given by $I_d = G_0\left[1-\left(\frac{V_0+V_g}{V_0+V_p}\right)^{\frac{1}{2}}\right]V_d$, where V_p is the pinch off voltage and G_0 the channel conductance with no bias on the gate.
6. We can use a JFET as a simple amplifier. The figure of merit of the device is the ***transconductance***, which is given by the equation $g_m = \left.\frac{dI_d}{dV_g}\right|_{V_g}$ where the vertical bar means at a particular value (of V_g).
7. We can use the transconductance to obtain the change in drain current we will get for a particular change in the gate voltage.
8. In a Metal Oxide Semiconductor FET (MOSFET) the gate is insulated from the channel using an oxide.
9. In the Enhancement mode version of the device there are two regions of one type around the source and drain contact and the rest of the material is of the opposite type.
10. We can create a channel between source and drain by applying a gate bias to drag charge carriers from the source and drain regions under the gate to allow electricty to be conducted.
11. We can also have a depletion mode device, where the channel already exists with no gate voltage applied.
12. The circuit characteristics of the JFET and MOSFET are very similar.
13. In a BJT we have two back-to-back pn junctions, where the middle region (called the base) is very thin.
14. The emitter is always doped heavily compared to the base so that charge carriers are injected into the base when the base-emitter junction is forward biased.
15. If the base is thin then the majority of electrons will diffuse across the base without recombining
16. These electrons will then be sucked into the collector by a reverse biased junction.
17. The key point is that the collector current is controlled by the current flowing through the base-emitter junction.
18. The base current and collector current will be in fixed proportion depending on the transistor geometry.
19. We can obtain a number of figures of merit for the BJT.
   a. The ***common base current gain*** is given by $\alpha_B = \Delta I_C / \Delta I_E$ and should be close to one.
   b. We can also write $\alpha_B = \gamma_E \alpha$, where γ_E is the ***emitter injection efficiency*** and α is the ***base transport factor***. Both these values should be close to one.
   c. This can be achieved for γ_E by doping the emitter heavily compared to the base and for α by making the base much thinner than the minority carrier diffusion length.
   d. The ***common emitter current gain*** is given by $\beta = \Delta I_C / \Delta I_B$ and we can show $\beta = \alpha_B / 1-\alpha_B$.
20. A common emitter amplifier can give both current and voltge gain. The common base amplifier can only give voltage gain.
21. We can obtain a small signal equivalent circuit as before where the input resistance is given by the reciprocal of the slope of the forward biased base-emitter junction around the operating point.