Lab 7 Background material

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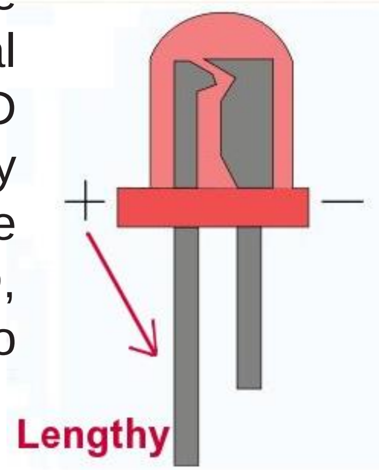
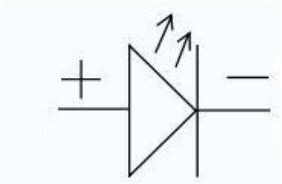
Basics of LEDs (1)

The LED is a light-emitting diode, and as it's name might suggest, it is essentially a diode with some unique properties that allow it to emit light. The output is usually of a specific color and is determined by the wavelength of the light emitted, which in turn is determined by the actual semiconductor compound used in forming the PN junction during manufacture. Typically red LEDs are constructed from GaAsP, and colors like yellow and orange are obtained by changing the amount of P and N mixed in.

The construction of a Light Emitting Diode is very different from that of a normal signal diode. The PN junction of an LED is surrounded by a transparent, hard plastic epoxy resin hemispherical shaped shell or body which protects the LED from both vibration and shock. Surprisingly, an LED junction does not actually emit that much light so the epoxy resin body is constructed in such a way that the photons of light emitted by the junction are reflected away from the surrounding substrate base to which the diode is attached and are focused upwards through the domed top of the LED, which itself acts like a lens concentrating the amount of light. This is why the emitted light appears to be brightest at the top of the LED.

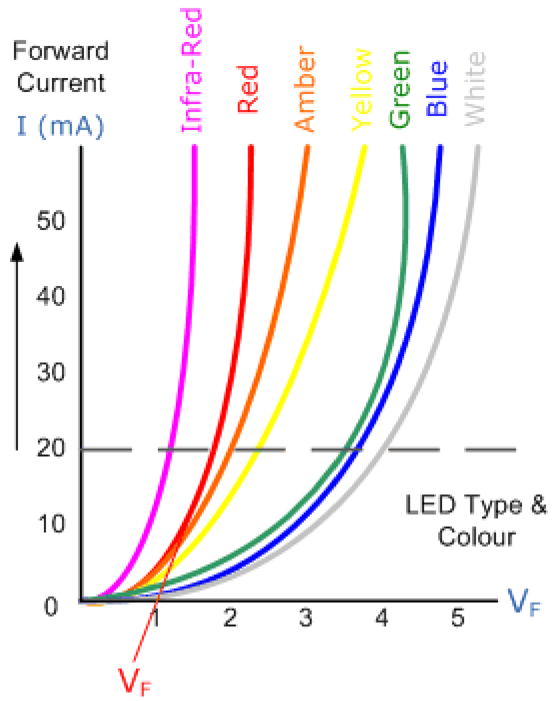


Just like a regular diode, in order to turn the LED ON, you must forward-bias it, and just like a regular diode, there is a minimum voltage at which it turns ON. Since the output of a LED is light, as you increase the current through the LED, the light will get brighter (At some point when it's bright enough, human eyes cannot distinguish between successive increase in brightness, so don't worry if you cannot observe this change for very bright LEDs)



Basics of LEDs (2)

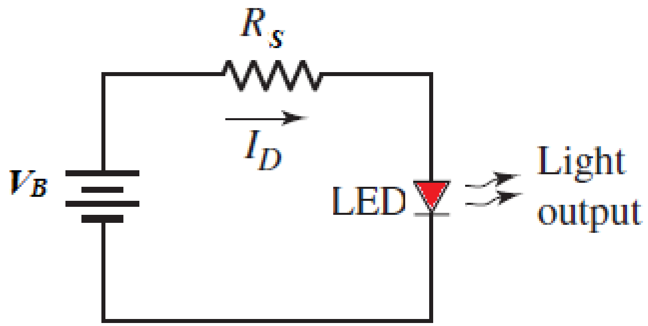
Shown on the right is a set of a characteristic curves for LEDs of different colors. These curves are not for the LEDs you will use in EE 438 labs, but are representative of the general trend followed by all LEDs. Typically IR and red LEDs have small forward voltage drops while blue and white LEDs have larger forward voltages. For example, in general, red LEDs have forward voltages between 1.7V and 2.1 V depending on the manufacturer., while green LEDs are typically between 2V and 2.8V.



The other thing to remember is that you need a substantial amount of current to achieve a desired amount of brightness. In this class, LEDs will typically operate anywhere from 2-3mA current, to about 20 mA current. In order to protect the LED from excess current, a series resistor is typically used to limit the amount of current.

Typically datasheets will list the maximum current rating of a LED. Knowing this,one can calculate the value of the resistor needed for current limiting as

$$R_S = (V_B - V_F)/ I_{D,max}$$

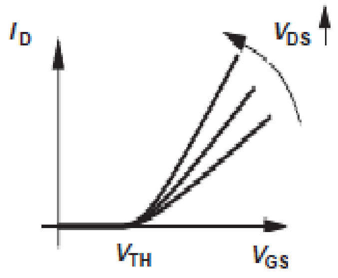


where $I_{D,max}$ is the maximum current rating of the LED and V_F is the forward ON voltage of the LED. For the EE 438 lab, assume $I_{D,max}$ = 20 mA

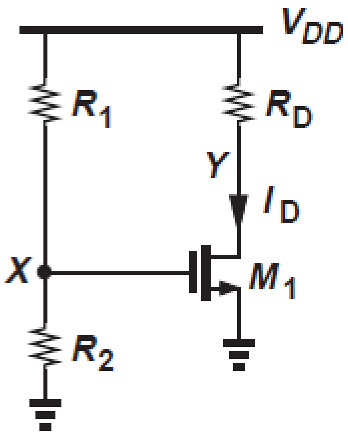
Common-source gain stages (1)

Common-source amplifiers are the workhorse of all analog circuits. They are used for general purpose gain applications, where a moderate voltage and current gain are needed. By making specific tweaks to the circuit design, we can obtain wide variety of designs tailored to specific applications such as high-speed, rail-to-rail output swing etc.

The first step in the design of an amplifier is biasing it at the correct bias point. Recall from your lectures that you want the device to be biased in the saturation region, which typically means choosing a V_{GS} that's not too large. However, we typically want a larger V_{GS} since that results in a larger drain current. Choosing a bias point is a compromise between these two choices. For discrete MOSFET design, the first step is to produce a set of I_D-V_{GS} curves like the one shown, and for a given bias current, we can determine the V_{GS} needed.



The most common bias circuit is the one shown on the right and is called voltage divider biasing. It uses the common supply, V_{DD}, to generate a voltage V_X at the gate node. If we know V_X, we can pick a set of resistors whose ratio yields the desired voltage at node X.

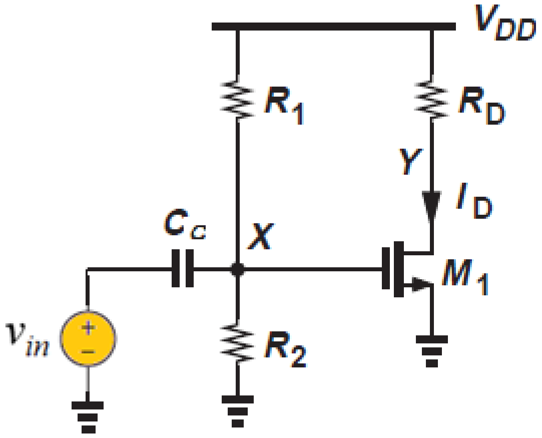


The resistor values in any bias circuit are chosen fairly large to reduce the amount of DC bias current through them. As a general rule, we want the amount of bias current to be 1/10th or 1/20th of the signal current, since it does not actively contribute to amplification. The other factors that guide the choice of resistor values include an input resistance or impedance specification.

Common-source gain stages (2)

Once you have determined the bias circuit, you essentially fix the operating current, the g_m of the device and hence the gain of the device. The next to step is to determine how to drive the amplifier. Most often, the choice of input signal, its frequency and any DC offsets are outside of the control of the designer. The designer has to design the amplifier to ensure it works with the input signal specification.

One of the most common choices a designer has to make is the use of a coupling capacitor. If the DC offset of the input signal is unknown or has a variable value, it's best to "block" this DC offset and only pass the input signal's AC content. This is most easily achieved by using a large capacitor, called the coupling capacitor (C_C) in between the input source and the input of the amplifier. This capacitor blocks DC signals and only passes signals at a frequency where the impedance of the capacitor is insignificant.



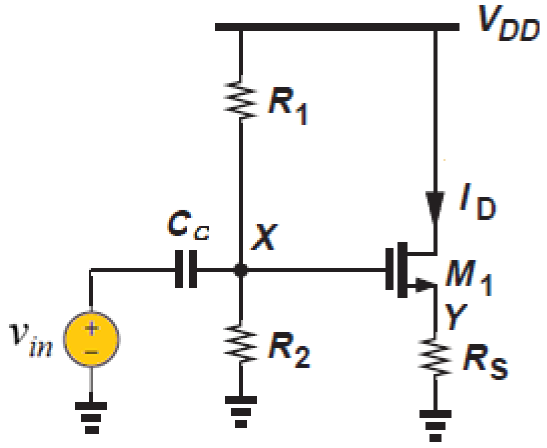
The capacitor is typically chosen such that $C \sim 10/(2.\pi.f_{in}.R_{eq})$

where f_{in} is the highest input frequency of the source, and R_{eq} is the equivalent resistance seen by the capacitor. For the circuit shown, $R_{eq} = R_1||R_2||R_{source}$ where R_{source} is the source impedance of the input source. For typical EE 438 lab circuits, with reasonably large values for R_1 and R_2 chosen, a 10µF capacitor is more than sufficient for 1 kHz signals.

Common-drain stages (1)

The second type of MOSFET amplifier to be considered is the common-drain "amplifier" circuit. An example of this circuit configuration is shown to the right and as can be seen, the output signal is taken off the source with respect to ground and the drain is connected directly to V_{DD}.

The DC biasing circuit is identical (in configuration, but not in the values of components) to that of the common-source stage typically, but if used as the 2nd stage of an amplifier, and if its DC coupled to the first stage, then it doesn't need a dedicated bias circuit. The output voltage of 1st stage will bias the common-drain stage. Of course, good design is needed to make sure it's of an appropriate value, such that the transistor remains in saturation, and conducts the right amount of current.



This is important because, typically in the 2nd stage, the common-drain stage is used to drive very low impedances (like a loudspeaker) or to drive a large current through the load (like a bright LED). In such applications, the common-drain stage is ideally suited to conducting large amounts of current and at the same time presenting a low output impedance to the load, and so the V_{GS} bias is higher than that of a typical common-source stage. The voltage gain of this amplifier is lower than 1, so it will attenuate the signal.