EENG-340 Curve Tracer

January 15, 2024

Design a Curve Tracer: A curve tracer is a circuit that helps to characterize the behavior of a semiconductor device, typically a transistor. The goal of this lab is to implement a curve tracer using a microcontroller and some kind of external display. As a designer you have flexibility to choose a microcontroller platform, and display technology. As you consider various options, be sure to document design choices, design calculations, simulations, and corresponding justifications.

Pre-Lab Plan:

Requirements

The BJTs and FETs we'll be using for this lab are signal level devices (see Table 1) not the high power variety (we'll get to those later!). This will greatly simplify the project since we won't need to supply large currents to test the devices. You should review the data-sheets for these transistors to identify the conditions under which they need to be tested. Before building any physical circuits, you'll need to design and simulate the circuits using the data from the data-sheets and verify that your design is viable.

Table 1: Transistors under test.

Item		
Type	Family	Part Number
NPN	BJT	2N3904
PNP	BJT	2N3906 (extra credit)
N-channel	MOSFET	5LN01SP
P-Channel	MOSFET	5LP01SP (extra credit)

BJTs

Collecting data from an NPN transistor: The first step is to design an interface for a microcontroller to collect data for an NPN transistor. The idea is to drive the base of the transistor with a fixed current, and then to sweep the voltage across the collector-emitter junction while monitoring the current through the collector, while holding the base current constant. See Fig. 1 for a schematic representation of the drive circuit. Of course R_c needs to be chosen so that the voltage available for $V_{c_{drv}}$ is sufficient to supply the needed collector current. By repeating this for a collection of base currents will produce a family of curves like those displayed in Fig. 2.

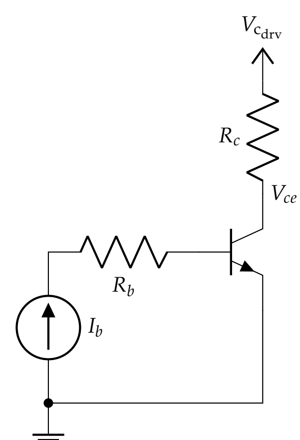

Figure 1: Driving a BJT to produce a family of V_{ce} curves at varying I_b.

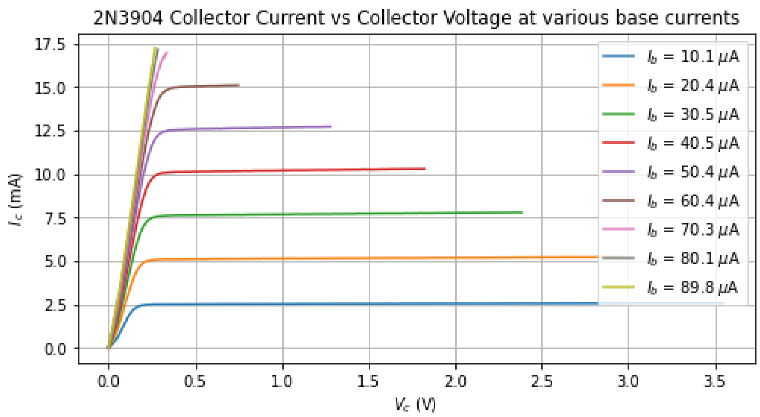

Figure 2: I_c vs V_{ce} for a family of base currents, I_b, in an NPN 2N3904.

You'll want to confirm that the base currents are indeed constant, which can be verified by measuring the voltage drop across the base resistor in series with the current source as shown in Fig. 1. If you plot collector current vs. base current for the data collected in Fig 2 you should get a graph like Fig. 3.

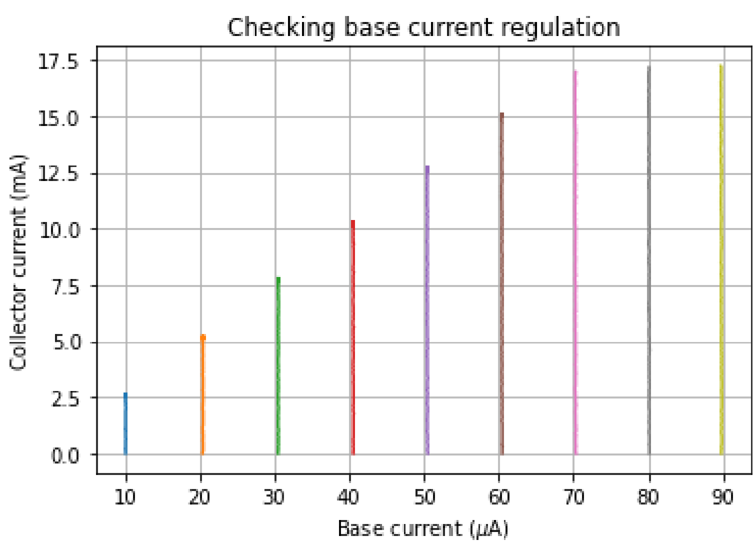

Figure 3: Validate that the base current really is constant as the collector current is varied.

THE PNP CASE: the circuit for PNP transistors (extra credit!) is very similar, except that the current source will actually be a "sink" rather than a source, and the emitter will be at $V_{c_{drv}}$ rather than the collector. You'll still want to set the base current to a fixed value while you sweep the collector drive voltage, and monitor both the collector and base currents, in a very similar way.

FETs

COLLECTING DATA FROM AN FET: For an n-channel MOSFET the situation is similar, except that rather than controlling the base current you'll be controlling the gate *voltage* as shown in Fig. 4. You'll need to consult the data sheets of the two MOSFETs we'll be using to determine what currents and voltages to expect. Rather than driving the collector, you'll be driving the drain voltage, and monitoring the drain current. There will be essentially no gate current, so no need to monitor that, though you will want to monitor the gate voltage. The p-channel MOSFET (extra credit) is just the opposite, similar to a PNP BJT relative to a NPN BJT. You'll still control the gate voltage but the drain and source will be reversed.

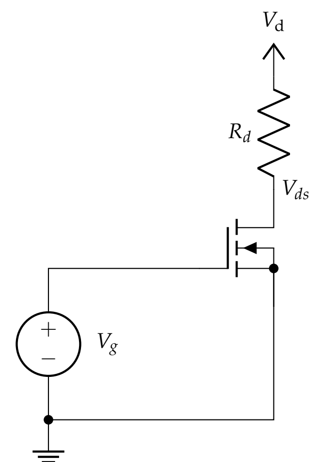

Figure 4: Driving an FET to produce a family of V_{ds} curves at varying V_g.

Output

Once the measurements are complete you'll need to come up with a plan to communicate those results from the microcontroller to a display device. You are free to use any communication channel you like, or you could drive VDACs to display the curves on an oscilloscope if you prefer. If you choose to use a serial communication protocol of some kind you do not have to display the curves in real time so long as you can capture the data and display it later in the report.

Implementation

The details of implementation are up to you. You need to document your design planning, simulation, and testing carefully and completely. There are four possible devices you can measure, but you should implement one BJT and one FET transistor at a minimum. Bonus points for real-time display of one kind or another.