BIEN4220: Laboratory 3 – Input / Output Interfacing

Introduction

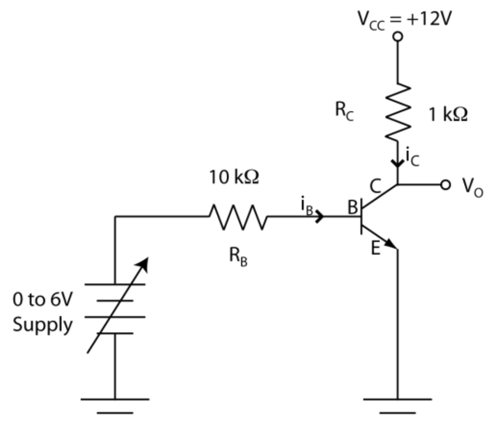
This laboratory exercise develops techniques in interfacing to the GPIO port on MSP430. Practical limitations on current sourcing capabilities of GPIO port pins on the MSP430 (as is true of nearly all uCs) are considered. Transistors are introduced as a means of switching loads with large current demands or interfacing to loads having different voltage requirements than does the uC.

Preparation:

1. Download the datasheet for the ZTX651 NPN transistor and review.
2. Prepare a data collection sheet for Part I (This could be a electronic spreadsheet).
3. For week 2, Design a NPN BJT circuit that will drive a heavy load like a 12V motor or solenoid from a MSP430 GPIO port pin. Include a fly-back (shunt) diode. Bring your design to lab.
4. For week 2, Describe in pseudo code how you will implement a PWM output channel using the MSP430F2013 in Part II below.

Procedure:

Part I: Intro to Transistors – the Common Emitter Circuit



1. Calculate the current gain (beta) for an NPN BJT transistor
   A transistor's current amplification can vary across a wide range (as seen in the data sheet). This section will show you how to measure beta (h_{fe}) and construct two graphs describing your transistor's amplification characteristics.
   a. Obtain a ZTX 650 or 651 transistor.
   b. Construct the circuit (right) on your breadboard. Use the triple-output power supply to source V_{CC} and the variable input voltage.
   c. Construct a voltage node data collection table. Prepare to measure V_{IN}, V_{BE}, and V_O. Include additional columns for base and collector currents. The more measurements, the better.
   d. Turn on the power supply. Set the +20V supply (V_{CC}) to 12V. Turn the 6V supply knob fully counterclockwise (zero voltage). Gradually increase V_{IN} until V_O is 6.0V.
   e. Measure the voltages across R_B and R_C to determine i_B and i_C. Compute $\beta = i_C / i_B$.
   f. Repeat these measurements for V_O = 2V and V_O = 10V. Compute the corresponding values of β. Is β the same at different values of collector current?
   g. Based on the component values and the average value of β for your transistor, calculate and sketch the expected *voltage transfer characteristic (V_O vs. V_{IN})* for your circuit. Be sure to label the voltages for significant points on the curve. This graph is very important for your transistor's amplification characteristics later. You should notice it has a few distinct voltage regions. Be prepared to describe what these regions are.
   h. Continue to perform more measurements to make a more resolute sketch. Set V_{IN} = 0V and measure V_{BE} and V_O. Increase V_{IN} in steps of 0.2V until you reach 2V. At each point, measure V_{BE} and V_O and record all values to a table.
   i. Now, increase V_{IN} in steps of 1V until you reach 6V. At each point, measure V_{BE} and V_O and record all values. **Plot V_{BE} vs. V_{IN} and V_O vs. V_{IN}.** The limiting value of V_O is the collector saturation voltage (V_{CEsat}). What is this value for your transistor?

   Show your plots to an evaluator. Be prepared to describe what you are showing me (especially V_O vs V_{IN}). Can you identify some regions of interest on the in/out plot?

   Evaluator Signature: ____________________

2. The transistor as a **linear amplifier**.
   a. Turn off the power supplies and the other equipment on the bench.
   b. Unplug the patch cord from the 0V – 6V power supply and plug it into your function generator. Set the function generator to produce a 100 Hz sine wave. Connect the output of the function generator to V_{IN} and to channel 1 of the oscilloscope. Connect scope channel 2 to V_O.
   c. Turn on the power supply, function generator, and oscilloscope. Set the function generator amplitude control to <u>minimum</u>, set the DC OFFSET so that the DC ***OUTPUT*** of your circuit V_O = 6V. **(Hint: Did you plot V_O vs. V_{IN}? What does it suggest your V_{IN} offset should be?)**
   d. Increase the amplitude of the sine wave until the peak-to-peak value of V_O is 4V. Measure the peak-to-peak value of V_{IN}.
   e. Compute the voltage gain of the circuit in the transistor's linear region: $G = \Delta V_O / \Delta V_{IN}$. Is this equal to the slope of the linear region of the transfer curve?

   Show your scope traces to your evaluator and the voltage gain that you have determined.

   Evaluator Signature: ____________________

3. The transistor as a **switch**
   a. Refer back to your plot from section I.1.i. Approximately what is the voltage V_{BE} when the transistor is in saturation? What practical limitations, if any, does this place on the voltage used to drive the common emitter circuit when the transistor is to be used as an amplifier? As a switch?
   b. Use a 0V to 2V square wave output of your function generator (0.2 Hz) to demonstrate the NPN Transistor as a current-controlled switch (i.e. with the transistor in saturation). Capture a scope screen shot with the input / output traces identified and indicate their amplitudes. Show this to an evaluator.

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   c. Replace the 1K-Ohm load resistor with a DC motor and parallel shunt (fly-back) diode that you will get from your TA. **Show this circuit to your evaluators** before you summon lightning.

   d. How much base current does it take to drive the motor fully on? How much current does the motor draw when running? At start-up? You can always change the period of the square wave.

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Part II: Driving Large Loads from the MSP430: Interfacing with Transistors

1. Create a new assembly-only project in CCS using the MSP430. Create a code module that will configure P1.1 as GPIO output and P2.6 as an interrupt-driven GPIO input with **pull-up resistor enabled**. The code is to drive a motor whenever a button (or wire) attached to GPIO port P2.6 is **pushed** (not held). Use good coding practice. Verify this desired operation on the scope.
2. Connect the ground of your microcontroller daughterboard to the ground of your drive circuit. Connect the output pin P1.1 to your drive circuit. **KEEP THE 12V and 3.3V MICROCONTROLER POWER SOURCES SEPARATE**. Run your system and debug it. Demonstrate your working system to your evaluator.

   Evaluator Signature: ____________________

3. Now, modify your code so that the speed of a DC motor is controlled using PWM on TA1 (Pin 4). You have code from previous labs that you can aftermarket to your current program. Demonstrate your ability to control the speed of the motor by stepping through the speed sequence {stationary, slow, medium, fast} using your button attached to P2.6. Use good coding practice. What duty cycle values did you choose for the four speeds? Demonstrate your working system to your evaluator.

   Evaluator Signature: ____________________