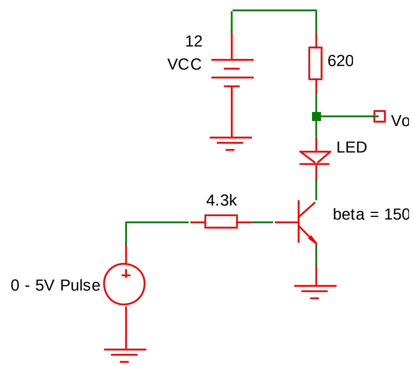
Union College
ECE363
Fall 2017
Assignment 1

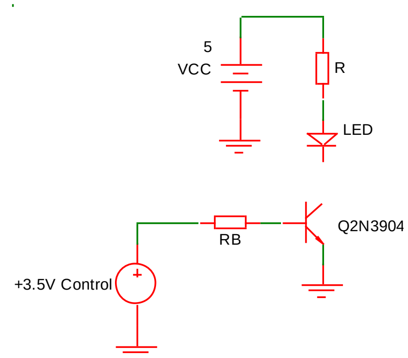
Due Thursday September 14, 2017

A. BJT switch analysis

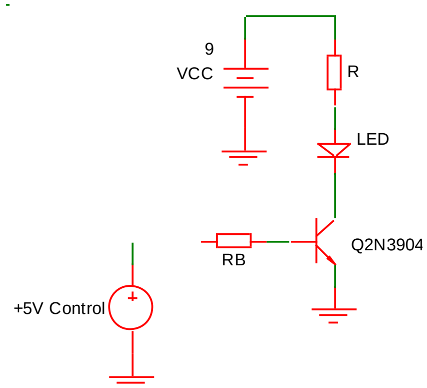


1) Consider the transistor switch shown to the right. Assume the transistor has $V_{BE,sat}$ = 0.7V and $V_{CE,sat}$ = 0.3V. Also assume the LED has a 2V forward voltage drop.
   (a) Compute the base current, LED current, and voltage Vo.
   (b) Is the transistor in "hard saturation" (e.g. $I_C \approx 0.1\beta I_B$)?
   (c) Assuming the input control voltage is a single 5V pulse, sketch Vo.

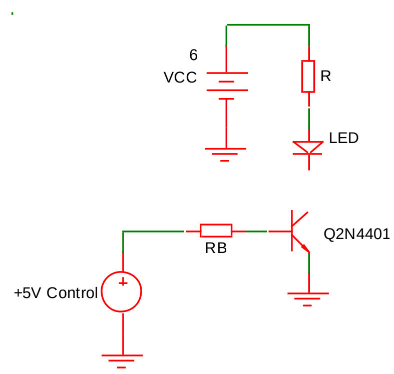
B. BJT switch design



2) Design a npn BJT switch to drive a green LED (V_F = 2.5V) with 10 mA of current. The control signal is 0 to +3.5V, and V_{CC} = +5 V. Use a 2N3904 transistor – check the datasheet (see course website) for worst-case values of β, $V_{BE,sat}$, and $V_{CE,sat}$.
   (a) Choose standard 5% resistor values (see course website for a table) for R and R_B. Choose R such that I_{LED} is NOT < 10 mA.
   (b) Compute the power dissipation in R.
   (c) Double your answer to (b) to determine the minimum power rating of R. Would you use a 1/8, 1/4, or 1/2 watt resistor?



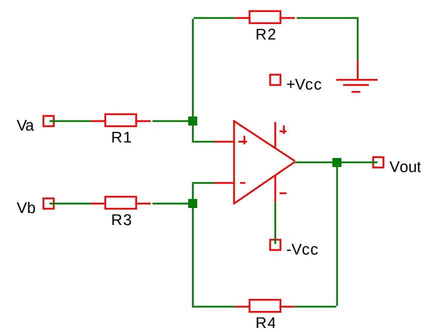
3) Design a npn BJT switch to drive a white LED (V_F = 3.5V) with 30 mA of current. The control signal is 0 to +5V, and V_{CC} = +9 V.
   NOTE: The "On Characteristics" table of the 2N3904 datasheet has worst-case values for I_C = 10 mA (h_{FE} = 100) and 50 mA (h_{FE} = 60). You can assume that h_{FE} @ 30 mA is somewhere between 60 and 100. Make a reasonable estimate (extreme accuracy is not necessary) and use this value for your design.
   (a) Choose standard 5% resistor values for R and R_B. Choose R such that I_{LED} is NOT < 30 mA.
   (b) Would you use a 1/8 , 1/4, ½, or 1 watt resistor for R?



4) Design a npn BJT switch to drive a power LED rated at V_F = 3.5V @ 300 mA. The control signal is 0 to +5V, and V_{CC} = +6 V. Use a 2N4401 transistor (see course website for datasheet).
   (a) Choose standard 5% resistor values for R and R_B. Choose R such that I_{LED} is NOT < 300 mA.
   (b) Would you use a 1/8 , 1/4, ½, 1, or 2 watt resistor for R?
   (c) Assuming an ambient temperature of T_A = 60 °C, what is the power rating of the transistor? Section 6.8 in the textbook has a useful discussion about power dissipation and derating factors.
   (d) Compute the actual power dissipation in the transistor.
   (e) Double your answer to (d), and determine if it is less than your answer to (c).
   NOTE: If the power rating is not high enough, then a heat sink is needed!

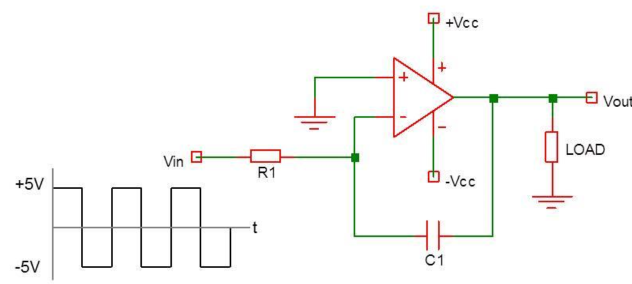
C. Ideal Op Amp Analysis

5) A difference amplifier does exactly what it says – it amplifies the difference between two voltages. This is a very useful function – a differential voltage signal is produced by many types of sensors and data transmission lines.



(a) Use the Golden Rules to determine V_{OUT} as a function of the inputs Va and Vb.
(b) Now let R3 = R1 and R4 = R2 and use your answer from part (a) to determine V_{OUT}.
NOTE: It turns out this simple difference amplifier is not that great, because resistor matching errors make it difficult to obtain good "common mode rejection ratio" (CMRR). We'll discuss better versions later in the course!

6) An integrator produces an output voltage V_{OUT} that is related to the integral of V_{IN}. One application of an integrator is to generate a ramp waveform by integrating a square wave. Another application is being part of an analog PID (proportional-integral-derivative) control loop to stabilize a temperature controller.

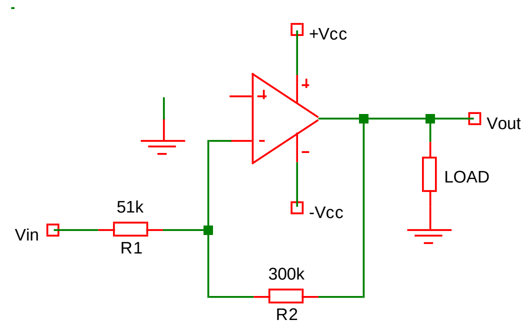


(a) Use the Golden Rules to determine V_{OUT} vs V_{IN}.
(b) Let R1 = 100 kohm and C1 = 100 nF. Suppose V_{IN} is a +/- 5V square wave with a 100 Hz frequency (see figure). Sketch the input and output voltages. Assume V_{OUT} = 0 as an initial condition. Make sure to label important features!

NOTE: It turns out this "ideal" integrator is not very useful because imperfections in real op amps cause the output voltage to wander with time. Practical integrators use a couple of extra components in parallel with C1, such as a JFET reset switch and a large resistor.

D. Real op amp analysis

7) Consider an inverting amplifier using a 741C op amp. The (+) input is directly wired to ground.



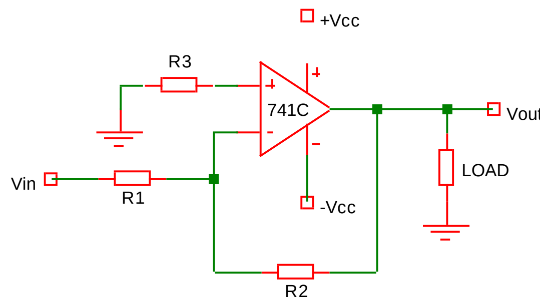
(a) What is the input impedance of the amplifier? Hint: See Section 18.3 for the R_{IN} of an inverting amplifier.
(b) Suppose V_{IN} = 0 and no trimming network. Given the worst-case values for $I_{in(bias)}$, $I_{in(offset)}$, and $V_{in(offset)}$, compute the output voltage offset due to each parameter.
(c) Is the main source of error due to input bias current, input offset current, or input offset voltage?
(d) What is the worst-case output voltage offset? Hint: Example 18-9 is useful.

8) Repeat Problem 8, but instead use a TL081C op amp (see course website for datasheet).

NOTE: The TL081C is a JFET-input op amp, so it has much lower input bias current and offset current than the LM741C. However, the input offset voltage is pretty high (the TL081 is a cheap op amp).

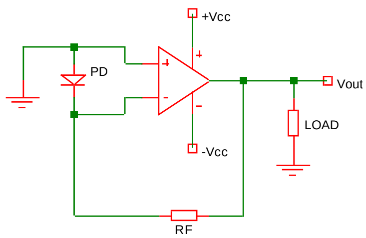
E. Op amp circuit design

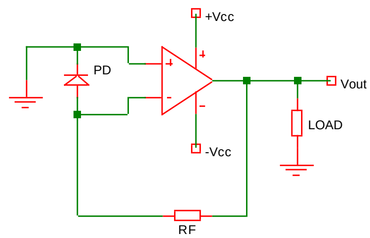
9) Design a DC inverting amplifier with an input impedance of at least R_{IN} = 10 kohm and a gain of at least V_{OUT}/V_{IN} = -50 (i.e. a gain of -50.5 is OK). Use a 741C op amp (see course website for datasheet). Assume the signal source impedance is negligible. Use standard 5% resistors.



(a) Determine R1 and R2 and choose 5% resistors.
(b) Compute the resistor RB that minimizes input bias current effects. Choose the closest 5% resistor value.
(c) Suppose a trimming network is used to remove any output voltage error. Let +/- V_{CC} = +/- 15V and V_{IN} = -200 mV, what is the smallest load resistance that can be driven by the op amp while maintaining the desired V_{OUT}? Use the plot of maximum output voltage swing in the Lecture 02 notes.

10) Design a photodiode amplifier using an OP906 photodiode and TL081 JFET-input op amp (see course website for datasheets). The amplifier output must be a POSITIVE voltage.





(a) You must choose either the left or right circuit shown above. Choose one and explain why.
(b) Choose the feedback resistor R_F (5% standard value) that gives an output voltage of 5V (or slightly higher) when the incoming light irradiance is 0.1 mW/cm^2. The "Light Current vs Irradiance" plot in the OP906 datasheet is useful.
(c) Assuming no trimming network, compute the worst-case output voltage error when the photodiode is in complete darkness. You must account for input bias current, input offset current, and input offset voltage.