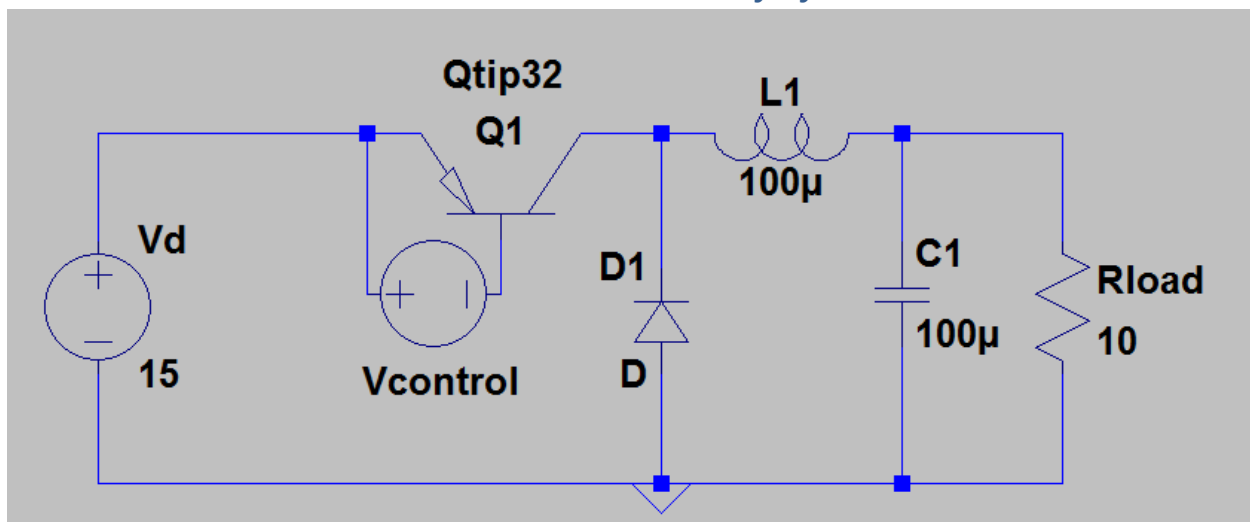


DC->DC Power Converters

Parts List:

- 1 dual DC power supply
- 1 Function generator
- 1 ground defeater (for function generator only)
- 1 Oscilloscope
- 1 hand held multi-meter
- 1 PNP BJT power transistor (TIP32)
- 1 power diode (HFA15TB60)
- 1 100 μ F electrolytic capacitor (15V or better)
- 1 10 Ω power resistor rated for 10W
- 1 TL494 PWM control chip
- 1 47 Ω resistor (1/2W)
- 1 150 Ω resistor (1/2W)
- 2 5.1k Ω resistor (1/2W)
- 2 47k Ω resistor (1/2W)
- 1 1M Ω resistor (1/2W)
- 1 1 Ω resistor (1/2W)
- 1 0.1 μ F ceramic capacitor
- 1 0.001 μ F ceramic capacitor

Build a Buck Converter Circuit-constant duty cycle



- Control Signal In: In the first iteration of the circuit signal V_{control} is from a signal generator. Use a $f=25\text{kHz}$ square wave with $V_{\text{pp}}=4\text{V}$. Control the voltage across R_{load} via the duty cycle D .
- Power in: $V_d=15\text{VDC}$.
- Power out: voltage across R_{load} .

The PWM Control Signal

Before we build the circuit we will look at the output of the signal generator on the oscilloscope.

Preparing the signal

- To drive the transistor properly we need to have the signal with floating ground. **Use the ground defeater on the function generator to make its ground float.**
- With a function generator's ground floating dial in a 25kHz square wave.
- Connect the function generator to the oscilloscope on channel 1. Adjust the trigger of the scope to get a clear look at the signal, a scale of 1V/div and $20\mu\text{s}$ should work well.
- Adjust the amplitude to get a $V_{\text{pp}}=4\text{V}$ signal.
- Press the DC-offset button and adjust the signal so that it oscillates between $V=0\text{V}$ and $V=4\text{V}$. (How do you set the scope to measure this?)
- Press the duty cycle button and adjust D using the knob.

Once you understand how to control your signal make a $f=25\text{kHz}$, $V_{\text{pp}}=4\text{V}$, $D=0.25$ signal and show me.

Construct the circuit

Construct a neat circuit. Use wires from the jumper wire kit as appropriate to neatly construct the circuit, this will make trouble shooting much easier. Connect the DC power supply and signal generator **but do not turn on the DC power supply**. Show me your circuit before you turn on the DC power supply.

Circuit Test

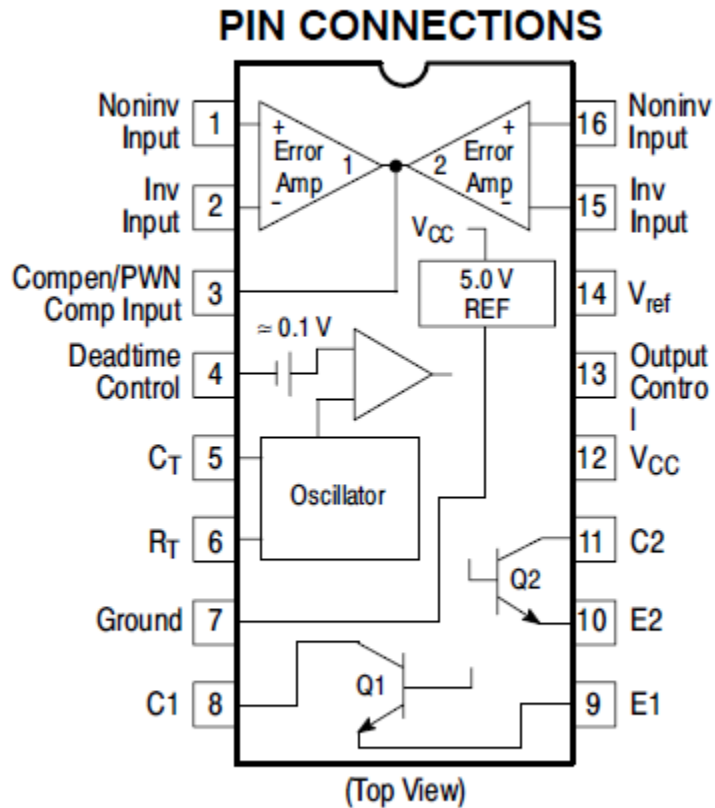
Once your circuit is checked turn on the DC power and test the circuit with a 50% duty cycle ($D=0.5$) control signal, (the default when the duty cycle button is off). Use the oscilloscope to measure the voltage across your resistive load. Does this behave as you would expect? Turn on the duty cycle button and adjust the duty cycle through its full range. Does this behave as you would expect?

Data Collection

1. Determine the efficiency of the converter at $D=0.2$, 0.4 , 0.6 , and 0.8 . Use a multi-meter on DC settings to measure the necessary voltages and currents.
2. Calculate ratio V_{out}/V_d for each of the above duty cycles.
3. Tweak your circuit so that you can view the current through the inductor, I_L , with the oscilloscope. Use DC coupling.
 - Sketch I_L vs time for $D=0.8$. Be sure to indicate where $I=0$ is in your sketch.
 - Vary the duty cycle to find the boundary between a continuous/discontinuous I_L . Sketch I_L as a function of time.
 - Determine the value of D at the boundary from your function generator, this can be done in a number of ways so be clear on your method.

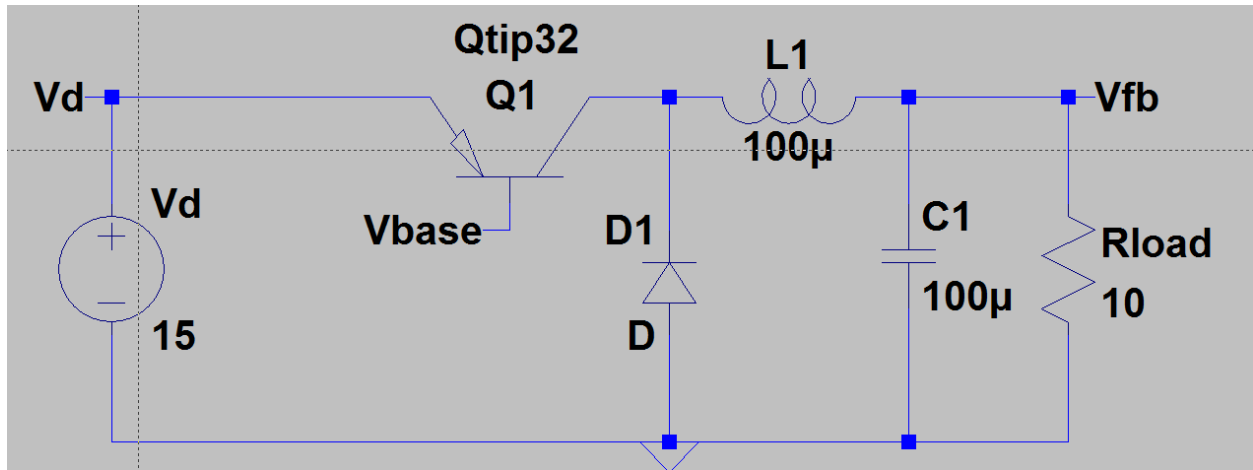
- Comparing D to V_{out}/V_d from step 2 does this value make sense? You might consider looking at section 7.3 from the textbook.

Using the TL494 to drive the transistor.



We will be drawing power from V_d both to run the control circuit chip and to give our DC- \rightarrow DC convert juice. This is why we built our original circuit with a PNP transistor (TIP32).

Power circuit



This is largely the same circuit, the function generator has been removed and three points of contact are labeled: Vd, Vbase, Vfb. Vbase is the voltage at the base of the PNP transistor and Vd-Vbase controls the output of the transistor. Vfb is the voltage across the load and is fed into the error amplifier along with Vgoal as part of the control circuit.

Build the control circuit as shown on the next page. Make a tidy circuit trimming resistors and capacitors so they are close to the breadboard and wire use jumper wires from the kit as appropriate. Use red only for Vcc and black only for ground.

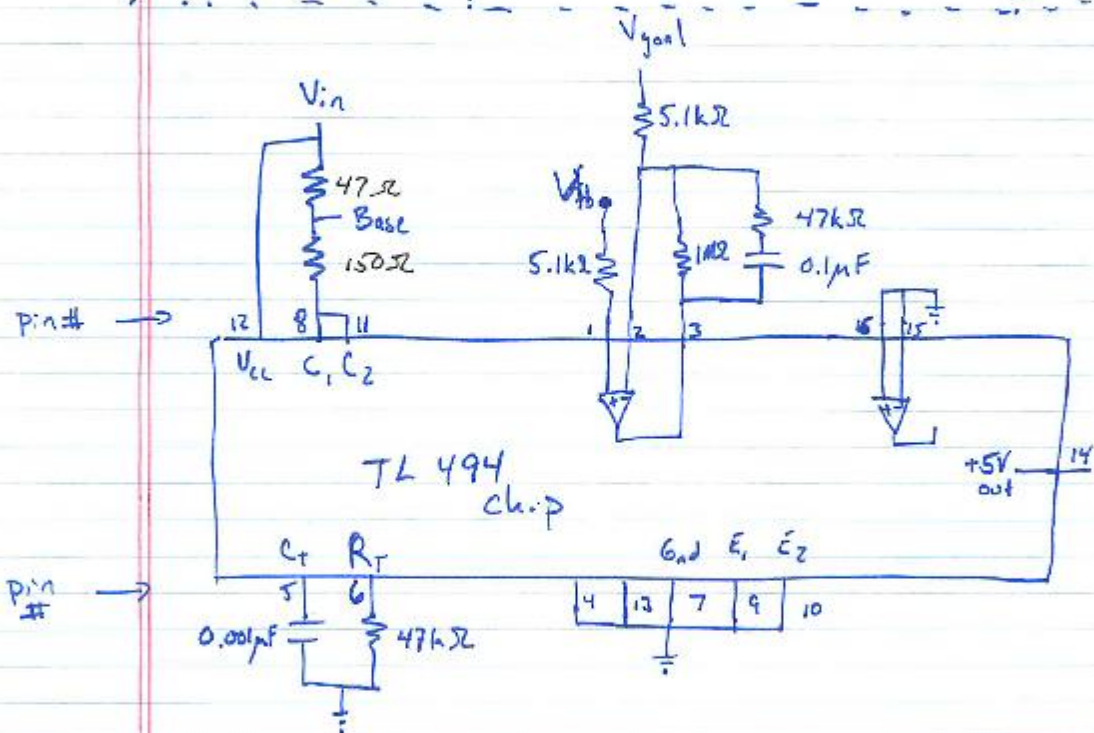
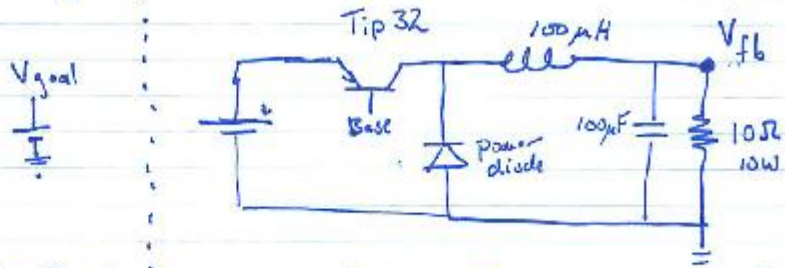
Note that there are three important pieces to the circuit not already in the chip are:

- The resistor/capacitor network connecting Vfb, Vgoal, and the output of the error op amp to the inputs of the error op amp. The $5.1k\Omega$ resistors connect Vfb to Vgoal. The other 3 elements are a filter that removes the high frequency from the amplifier feedback loop.
- The resistor network connecting the transistor base to both Vd and $0.75 V_d$
- The timer RC circuit that sets the period of oscillation $F_{osc} = 1.1 / (R_T C_T)$

Connect the Buck circuit to the control circuit and use the output of pin 14 for Vgoal. Measure the voltage across Rload and report it here:

Now use the second channel of the DC power supply for your Vgoal. Measure and report the voltage across Rload for Vgoal=3V, 6V, 9V, and 12V. Also measure the current supplied by the power supply for Vgoal at each of the above voltages. **Be sure not to keep the Vgoal at 12V for long. What would be damaged if you did?**

Regulated Buck Converter



$$F_{osc} \approx \frac{1.1}{C_T R_T}$$

Function generator sourced V_c , measuring efficiency and duty cycle

	D=0.2	D=0.4	D=0.6	D=0.8
V_d				
I_d				
P_d				
V_{out}				
I_{out}				
P_{out}				
η				
V_{out}/V_d				

Sketch of I_L vs t at $D=0.8$

Value of $D=D_b$ at boundary between continuous and discontinuous inductor current:

Sketch of I_L vs t at $D=0.8$

Q. 4 answer:

Precision/feedback control of V_{out}

V_{goal}	V_{out}	% difference
3V		
6V		
9V		
12V		

Device that could be damaged at $V_{out}=12V$ and calculation to back up your claim: