

ECE3424 Electronic Circuits Laboratory

Experiment #4

AC-DC converters and Charge-pump circuits

vers 1.3

OBJECTIVE: Assess and evaluate the characteristics of the half-wave AC-DC converter with capacitance filtering and rise time and loading characteristics of the diode-capacitance charge pump.

Background: The AC-DC converter comes in two basic topologies (1) half-wave rectification (HWR) and (2) full-wave rectification (FWR). They are a consequence of the diode's non-linear conductance across zero which gives it the capability to discriminate between forward and reverse polarities.

In order to qualify the output for application the topologies usually include capacitive or inductive elements to suppress variations in the amplitude. The most primitive (and simplest) topology is that the capacitive filter shown by figure 4-1.

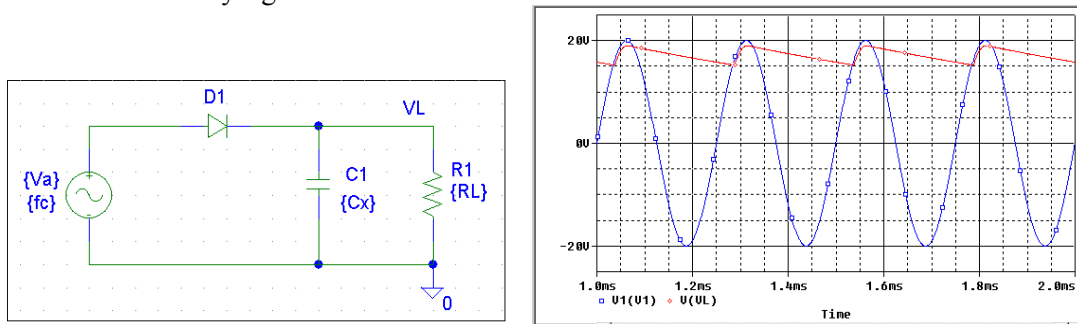


Figure 4-1. Half-wave rectification (HWR) and capacitance filtering.

The basic full-wave rectifier is shown by figure 4-2, for which the efficiency of the conversion is higher. A caveat of this circuit is that both the load R_L and the input V_I cannot share a common ground unless the FWR either has transformer isolation (as shown) or a floating ground, since otherwise there will be a sneak path through ground that will short out one of the diodes.

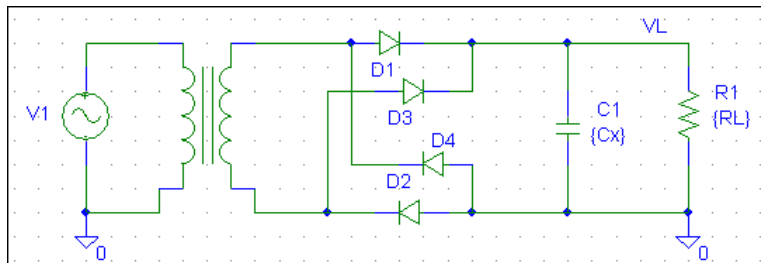


Figure 4-2: Full-wave rectifier (FWR) with capacitance filter

An often overlooked extension of figure 4-1 is the diode-capacitance charge-pump, also known as the Voltage multiplier, shown by figure 4B-1. Output voltage is effectively $V_L = 2N(V_P - V_D)$. The output capacitance C_I no longer serves just for reduction of V_R but as an energy storage reservoir C_L . The higher output voltage will also store more energy (w) since

$$w = \frac{1}{2} C_L V_L^2 \quad (4-1)$$

The charge-pump circuit should be treated with mild caution since higher voltages can be achieved and the energy stored on C_L could be sufficient to cause a healthy spark and a nasty burn if the energy passes through a finger or forearm. For the tests sponsored by this lab exercise the charge pump will be kept to the 3-stage level.

PROCEDURE:

A-1. Set up the HWR circuit of figure 4A-1 on your protoboard and MFJ prototyping box using either a 1N914 or a 1N4148 diode with R_L (resistance load) = resistance box. Set the input source to 4kHz sinusoidal at 10V pk-pk (amplitude $V_p = 5.0V$).

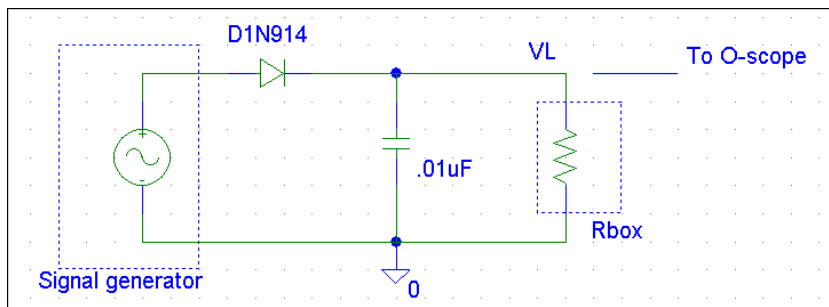


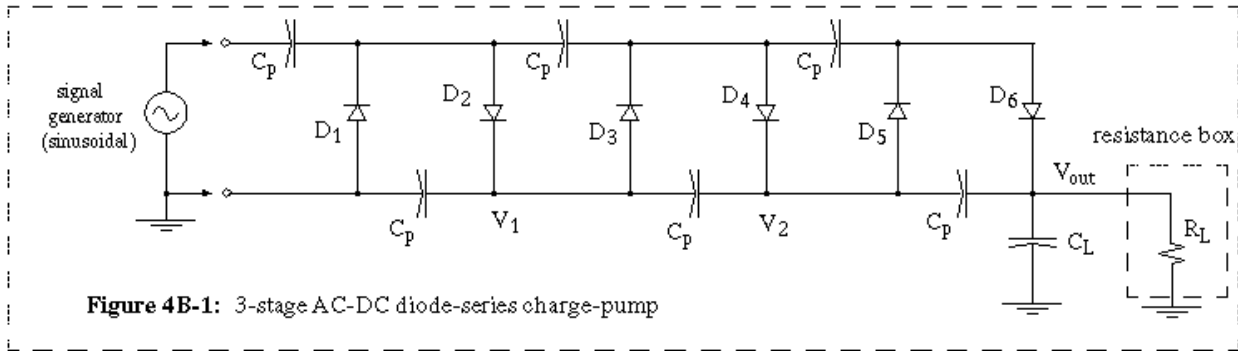
Figure 4A-2. Half-wave topology test set up.

A-2 With the load (R_{box}) set to $99,999\Omega$ make a check run to confirm that the output is of like form to that of figure 4-1. Measure V_R and V_P using your oscilloscope cursors. Include an estimate of measurement error in all values of measured data.

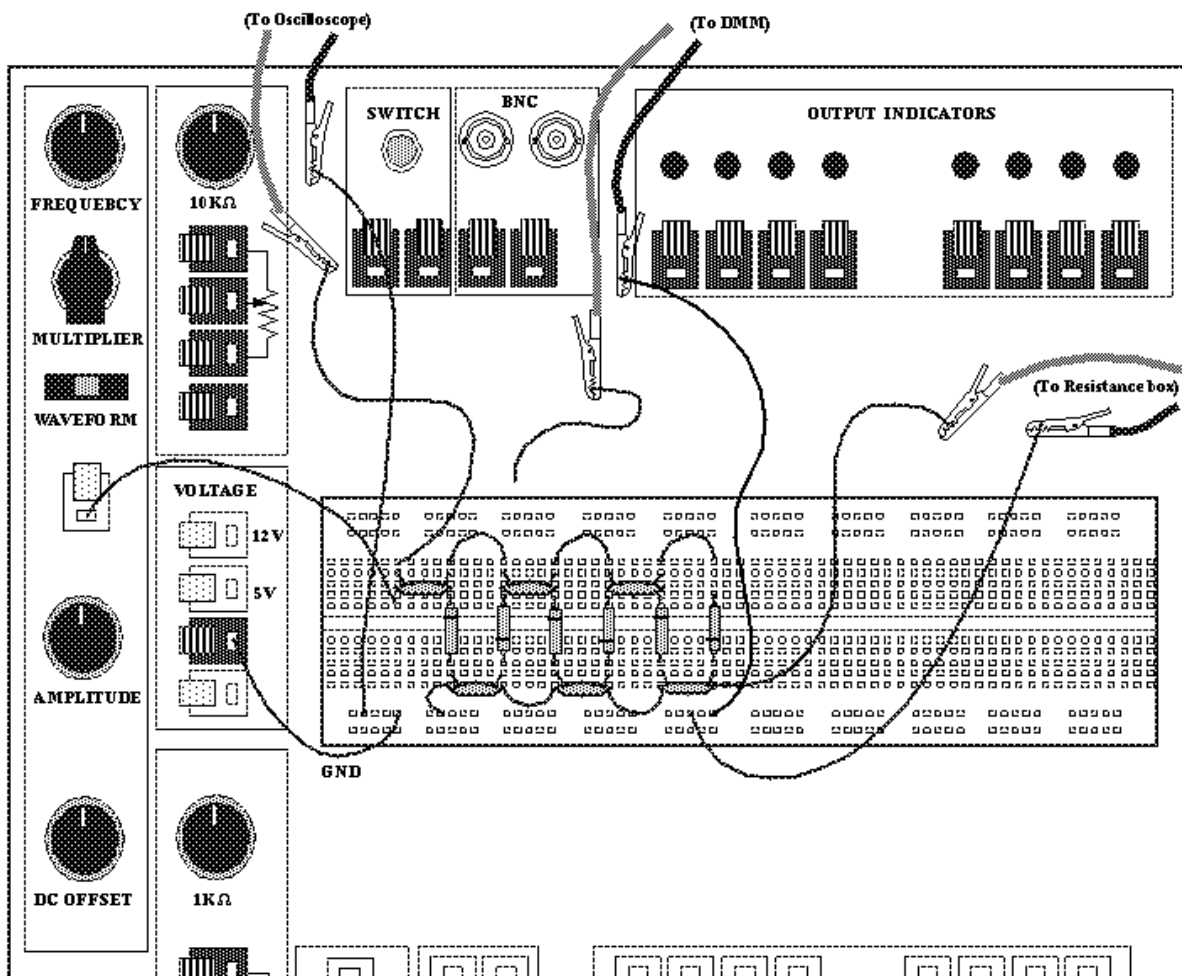
Reset R_{box} to start value $999,999\Omega$ and step decrease to 99Ω with measurement of V_R and V_P for each setting. The reason that the R_{box} is set at 9999999999 is that deletion of the lead digit reduces the load by one order of magnitude without risking any transition damage to either the R_{box} or to the circuit.

A-3. Reset the R_{box} to 9999Ω . Vary the input amplitude of the input from $V_P = 1.0V$ to $V_P = 8.0$ (if your signal generator can accomplish this reach) in steps of $1.0V$ and measure V_R and V_P for each case.

B-1: Construct the diode-capacitance circuit shown by figure 4B-1 on your prototyping motherboard with 1N4148 switching diodes and charge pump capacitances of $0.001\mu F$. Storage capacitance $C_L = .01\mu F$. R_L is the resistance box, set initially to $9,999,999\Omega$



Suggested place and wiring setup of the circuit is shown by figure 4B-2. The layout topology can be constructed in a considerably more compact form, but for simplicity of the tests it is probably best to track its topology to that of the circuit diagram.



The diode rectification effectively directs the current to flow only in one direction and thereby charge up each capacitance in succession. The sum of the voltages captured across the capacitances gives a voltage multiplication with V_L across the load of

$$V_L = 2N \times (V_P - V_D) \quad (4-2)$$

and which is a result that we would like to confirm, as well as the constraints on this topology due to RC time constants and source frequency.

B-2: With R_L at $9,999,999\Omega$ and source $V_P = 3V$ (6V pk-pk) at 4 kHz signal to the input (monitor with O-scope). Make a measurement of V_{out} using (1) the DMM and (2) the O-scope. Use the O-scope to measure the ripple voltage (peak-peak) of the signal at V_{out} .

B-3: Reset the $R_{box} = R_L$ to $999,999\Omega$ and repeat the measurements of part B-2. You should begin to see a more appreciable ripple (on the order of 200mV) at V_{out} , and the voltage levels will be reduced.

B-4: Repeat steps B-2 and B-3 but for $V_P = 5V$ at 4 kHz.

B-5: Repeat steps B-2 and B-3, but for $V_P = 4V$ and 40 kHz.

B-6: Replace all C_P and C_L with $.033\mu F$ capacitances and repeat steps B-2 thru B-5.

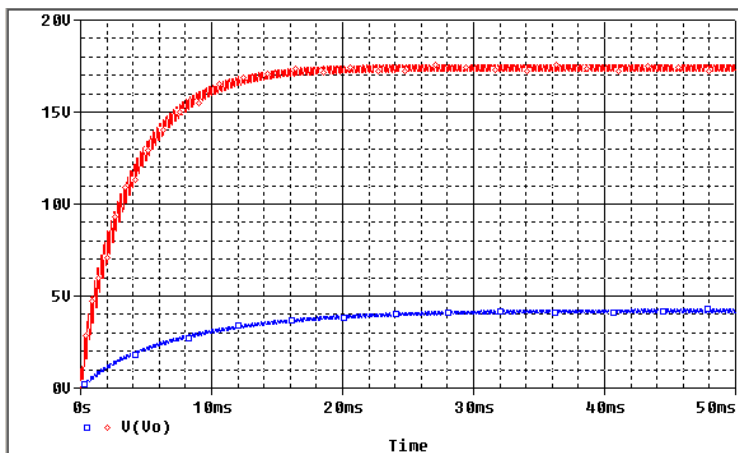


Figure 4B-3 Expected output $V_O(t)$ for 4.0V at 4kHz source (and for charge pump capacitances $C_P = .001\mu F$ and $.033\mu F$, respectively).

REPORT and ANALYSIS:

A. Transfer your measurement and accuracy data to your **Excel** database, Use the database and the formulae to identify V_{DC} and V_L . Compare results to calculations using equation (4-1) and (4-2) using the X-Y plot function of Excel.

B. Execute both of the test setups in pSPICE using the device model for the 1N4148 (or 1N914) diode. Enter the same data points in the data table at the same test levels as your measurements. Show comparisons by means of the X-Y plot function available in Excel.

**You may find it of benefit to parameterize part values and make use of the Performance Analysis option in pSPICE, which lets you create data (and plots) that show circuit performance as a function of parametric value. And the data can also be copied into Excel.

Compare your results on the charge-pump of figure 1.B-1 to a SPICE analysis that shows output node $V_o(t)$ through approx 100 cycles of the AC input source. In your pSPICE analysis the PART that you should use for *the input source* is VSIN. To display $V_o(t)$ as a function of time select the menu **Analysis > Setup > Transient** with final time = 100/freq (gives you 100 cycles). Make the step ceiling = (final time)/1000

You should find out that there is a rise time τ associated with V_L for the charge pump that is visible with the pSPICE simulation. Extract τ and determine its relationship to C_p and to frequency f .

Appendix A-1:

Extra diode and capacitance parts. You should have a sufficient number in your parts kit, as supplemented). But if not some extras may be located in the parts box in the parts/wires drawer of your workstation.

