

# EEE118: Electronic Devices and Circuits

## Lecture VI

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## Last Lecture: Review

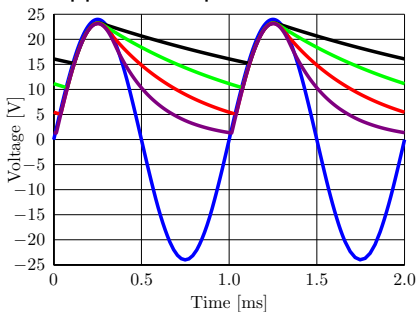
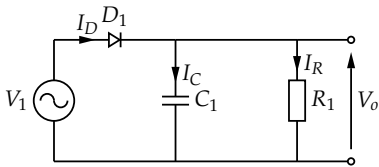
- 1 Introduced circuits driven by pulses.
- 2 Noted that, in EEE118 we are concerned with how to treat the circuit operation rather than how to solve differential equations (we will use the solutions without derivation).
- 3 Developed the idea of a time constant.
- 4 Looked at a low pass filter driven by a square pulse.
- 5 Worked through an “exam strength” pulse circuits question.
- 6 Introduced five diode circuits driven by sinusoids or waveforms derived from sinusoids. These form the basis of discussion from now until after the holidays.
- 7 Begun a description of operation for the peak detector circuit by thinking about the diode’s conduction state as a function of time. A technique we will return to in the future.

# Outline

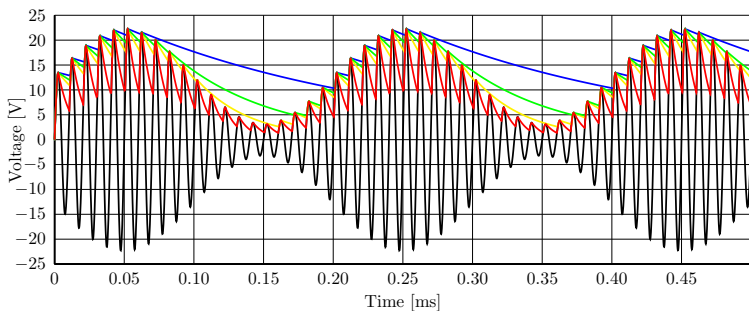
- 1 Peak Detector
  - Signal Detectors
- 2 Voltage Clamp
- 3 Voltage Doubler
- 4 Voltage Multiplier
- 5 Homework 2
- 6 Review
- 7 Bear

## Peak Detector Continued

The time constant  $R_1 C_1$  determines how effective the peak detector is at maintaining the peak signal voltage. It is common to arrange  $R_1 C_1 \gg t_p$  where  $t_p$  is the period of the waveform. When  $t_p = R_1 C_1$  (green line) the peak detector fails to maintain the peak voltage for the majority of the cycle. As  $R_1 C_1$  is decreased further the exponential nature of the voltage decay becomes apparent and the triangular ripple assumption is broken.



Peak detectors extract information from AM radio signals. RC is a compromise between a value large enough to give a small value of ripple at the carrier frequency and a value small enough to allow the capacitor voltage to follow the modulation envelope.



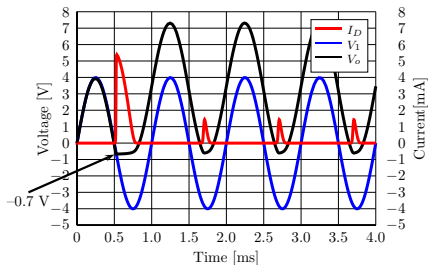
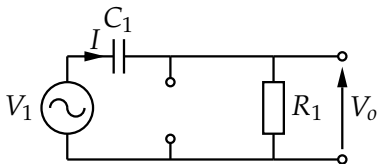
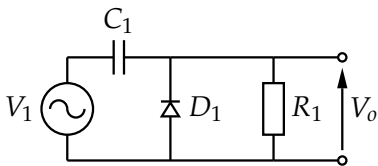
Notice that  $V_1$  (Black), the modulated carrier, has an average value of zero whereas the peak detector output has a non-zero average and a periodicity that is related mainly to the modulation envelope rather than the carrier.

# Voltage Clamp

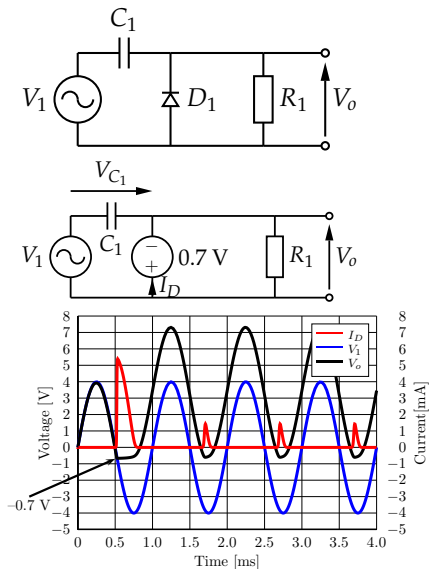
## Clamp Description

A circuit that fixes or “clamps” either the positive or negative extreme of a waveform to a defined voltage level.

There are some signals that transmit DC level information as part of the signal. The output of a signal detector is simply a waveshape consisting of a DC component and a superimposed signal waveshape. A clamping circuit discards the DC component and defines the DC level of either the positive or the negative signal peaks. Because clamping circuits restores the correct DC levels contained in signals, they are sometimes called “DC restoration circuits” and this term is used frequently in the context of analogue television video signals.

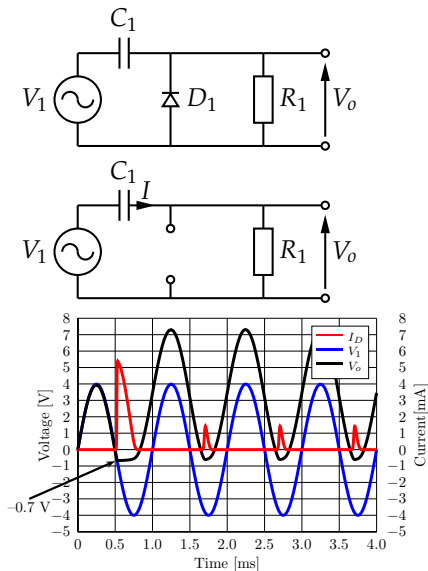


- For the first  $1/2$  cycle from 0 to 0.5 ms  $V_1$  is positive. The rising  $V_1$  will drive current through  $C_1$  towards the output.
- The diode does not conduct, so current only flows through  $R_1$
- Since  $R$  is large, the current flowing does not significantly charge  $C_1$
- There is negligible change of charge in  $C_1$  and so negligible change of voltage across it. So  $V_o$  follows  $V_1$



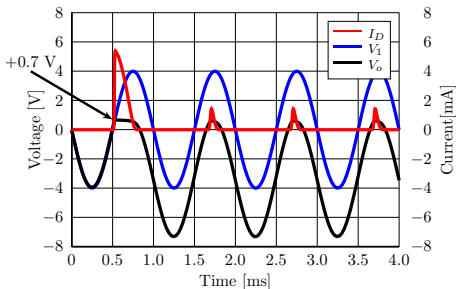
- In the second half cycle  $V_1$  falls and  $V_o$  follows until it reaches  $-0.7$  V
- The diode conducts from  $0.5$  ms -  $\sim 0.75$  ms and holds the voltage at  $-0.7$  V. By the time  $V_1$  has reached its negative peak at  $0.75$  ms a charge of  $C_1 \cdot (V_{1pk} - 0.7)$  has been stored
- The voltage across  $C_1$  is now  $V_{1pk} - 0.7$ .





- In the last quarter of the first cycle,  $V_1$  begins to increase again. This rising voltage tries to drive a current through  $C_1$ .
- $D_1$  does not support current flow in this direction. A small discharge current flows from  $C_1$  through  $R_1$  (which is high valued).
- $C_1$  is not significantly discharged so  $V_{C_1}$  remains approximately constant.

- $V_1$  could have any additional DC voltage superimposed without affecting the circuit behaviour. The only limit is the voltage rating of the capacitor,  $C_1$
- In practice  $C_1$  must be able to lose charge slowly so that the circuit can follow slowly changing signal amplitudes.  $R_1$  must be finite. But must be sufficiently large to make the charge loss per cycle relatively small
- If the diode is turned around, the positive peaks of  $V_1$  are clamped to  $+0.7\text{ V}$  and the output goes negative.

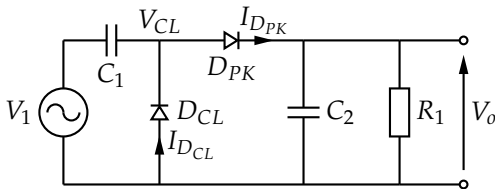


## Voltage Doubler

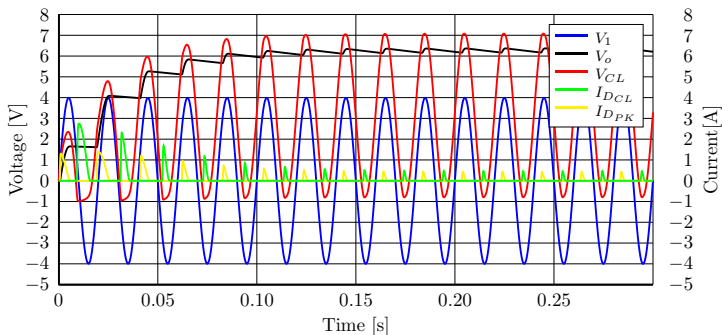
A **voltage doubler** is a **voltage clamp** followed by a **peak detector**, also called a **peak to peak** detector.

The diode clamp takes a sinusoidal signal and clamps the negative peaks to  $-0.7$  V. The peak detector detects the positive peaks to give an output voltage approximately twice what would be expected without the clamp.

$C_1$  and  $D_{CL}$  form the diode clamp and  $D_{PK}$  and  $C_2$  form the peak detector.  $R_1$  is the load.



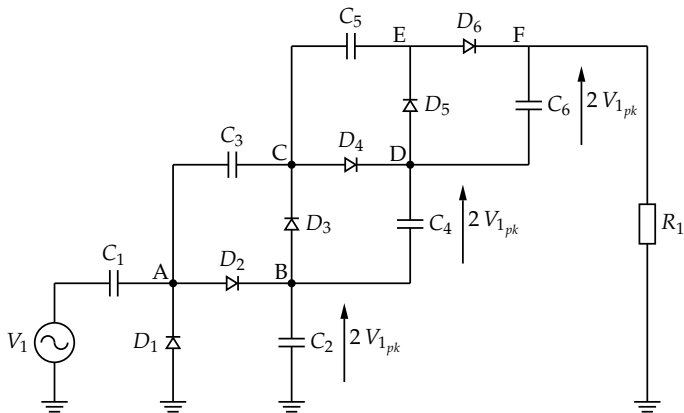
The peak to peak detector is used in signal applications and in low power, power supply applications. The circuit is one of a class of “diode pump” circuits.



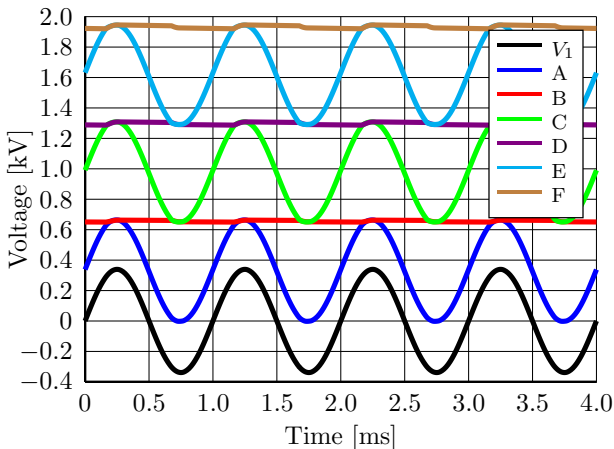
- When  $V_1$  is low, charge flows through  $D_1$  into  $C_1$  as described in the diode clamp explanation.
- When  $V_1$  goes high, that charge is tipped through  $D_1$  into  $C_2$ ,  $C_2$  is essentially a charge reservoir which is slowly depleted by  $R_1$ .
- If  $C_2$  is to be effective, the current in  $R_1$  should yield a small fall in voltage across  $C_2$ .

- The output voltage is then determined by the equilibrium condition; charge pumped from  $C_1$  to  $C_2$  per second equals the charge lost through  $R_1$  per second.
- Assuming that  $C_2$  is an effective reservoir,  $C_1$  affects the equilibrium output voltage and the time it takes the output to reach equilibrium.
- If  $C_1$  is small compared to  $C_2$  it will only be able to transfer a small fraction of the charge needed to fill  $C_2$  on each cycle. Charge will build up in  $C_2$  over several input cycles (hence  $V_o$  will build up over several cycles) and because the rate at which charge is entering  $C_2$  is small,  $V_o$  is sensitive to small current drains such as that through  $R_1$  because of the need to maintain an equilibrium between the charge flowing into and out of  $C_2$ .
- A value of  $C_1$  that is large compared to  $C_2$  can pump a large charge per cycle into  $C_2$  so  $V_o$  rises rapidly and is relatively insensitive to current drain through  $R_1$ .

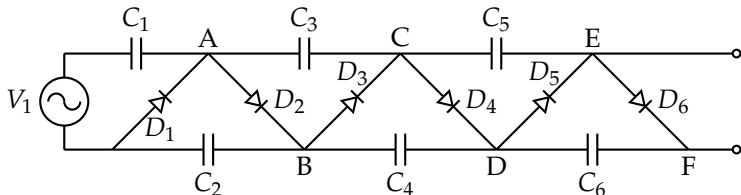
The peak to peak detector circuit can be extended to obtain higher output voltages.  $C_1$ ,  $D_1$ ,  $C_2$  &  $D_2$  form a peak to peak detector that generates a voltage across  $C_2$  of  $2 V_{1pk}$ .  $C_3$ ,  $D_3$ ,  $C_4$  and  $D_4$  form another peak to peak detector.  $D_3$  clamps the negative peak of the signal to a voltage of  $2 V_{1pk}$ .



The positive peak of the voltage at B is  $2 V_{1_{pk}}$  above its clamped negative peak ( $-0.7 \text{ V}$ ) giving a peak detected voltage across  $C_4$  of  $2 V_{1_{pk}}$ . Each peak to peak detector provides an additional  $2 V_{1_{pk}}$ . A total of  $6 V_{1_{pk}}$  exists across  $R_1$ .  $V_{1_{pk}}$  has been multiplied 6 times.



The circuit is normally presented slightly differently.



Applications,

- Cathode ray tube based displays 25 kV. A *flyback converter* (EEE223/EEE307) sometimes used instead
- In integrated form to multiply 5 V pulses up to around 100 V to drive the small plasma displays often found on automotive and 'high-end' CD players
- In experimental physics research to obtain extremely high voltages - of the order of MV - for electric discharge studies. Also electron microscopy

All these applications require low currents - typically a few tens of  $\mu\text{A}$ . The circuit is not suitable for high currents.



## Homework 2

It should be possible to fully attempt Homework 2 now.

It should be possible to fully attempt the Diode, Resistor and Capacitor Circuits problem sheet as well.

# Review

- 1 Finished looking at the **peak detector** circuit.
- 2 Considered the use of the **peak detector** in **AM radio demodulation**
- 3 Introduced and described the operation of the diode **voltage clamp** circuit. The clamp can be broken down into,
  - $0^\circ - \sim 180^\circ$  - Diode not conducting, negligible charging of C through R.
  - $180^\circ - \sim 270^\circ$  - Diode conducts C charges through D.
  - $270^\circ - \sim 360^\circ$  - Diode not conducting, small discharge current flows from C through R.
  - All following cycles - Diode briefly conducts around  $\sim 270^\circ$  to recharge C
- 4 Connected a **peak detector** to a **voltage clamp** to form a **peak to peak detector**

## Review Continued

- Considered the **equilibrium condition** that defines how ideally the **peak to peak detector** acts as a **voltage doubler**
- Developed a three stage voltage doubler and looked at the voltage on the clamp and peak detector at each stage.
- Observed that the voltage doubler is often drawn as a ladder in which capacitors are the “edges” and diodes are the “rungs”

