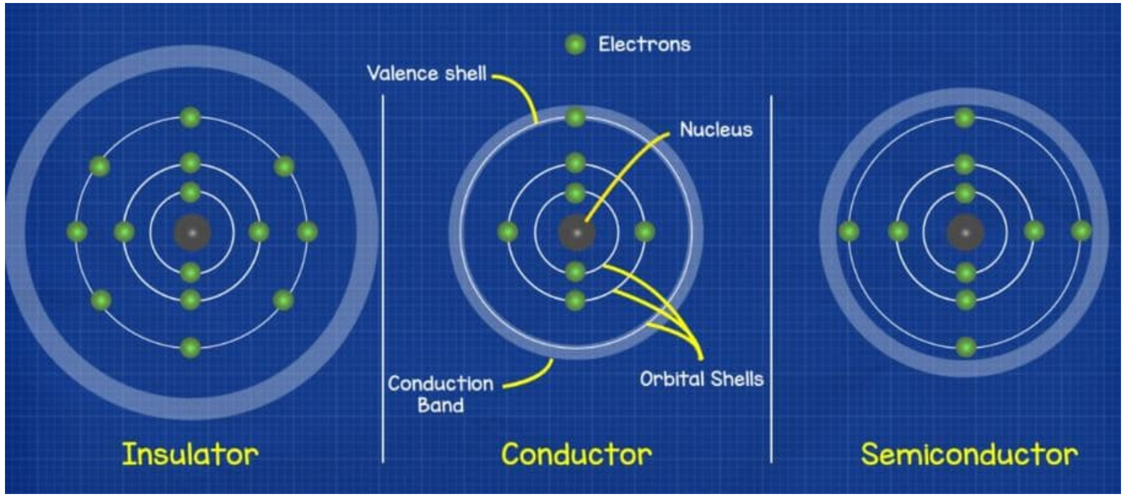
Electronic Circuits

Lecture 3.2: Semiconductor Principles & Diodes

Material Types

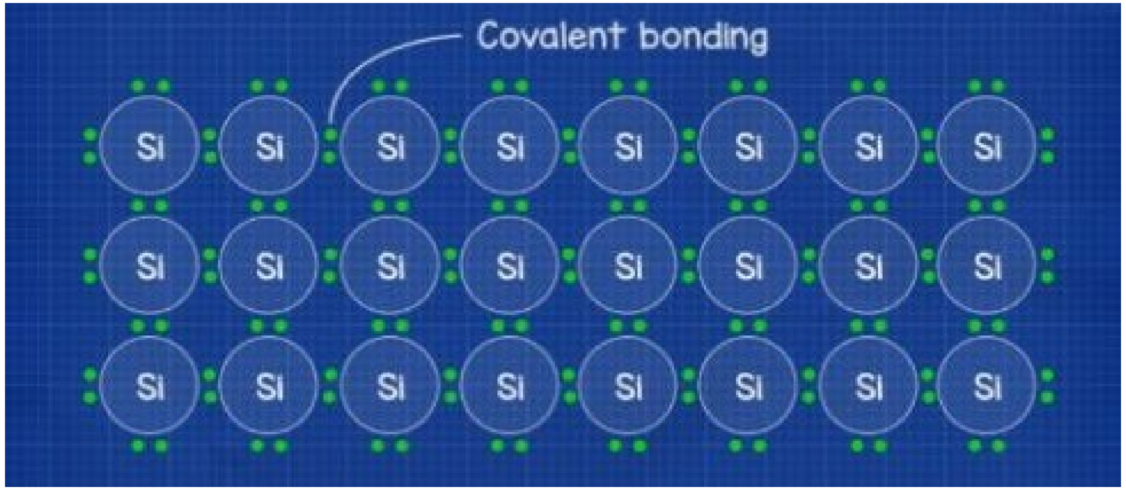


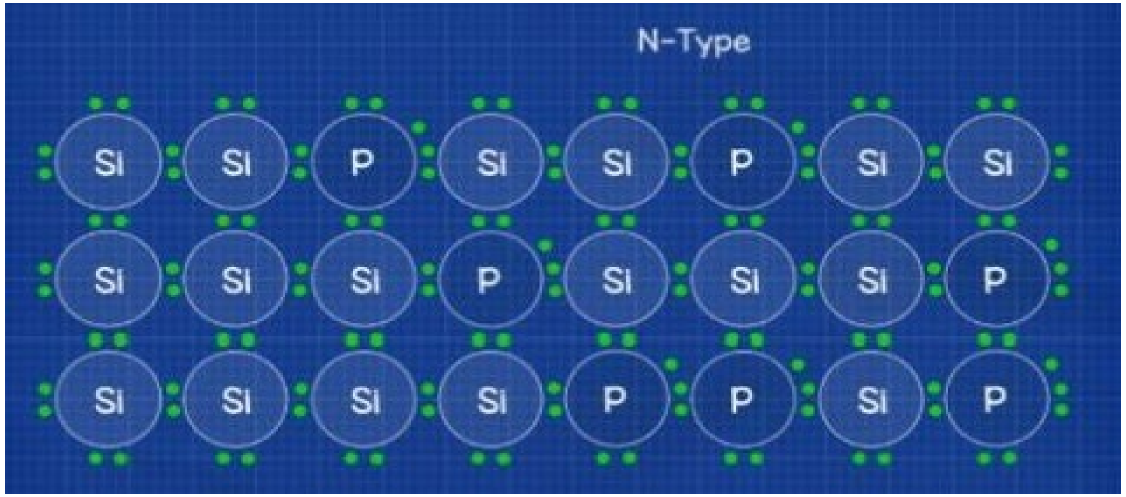
- With a conductor, the outermost shell has only few electrons. The outermost electrons can reach the conduction band, then it can freely move from the atom to another.
- With an insulator, the outermost shell is packed. Therefore, electricity cannot flow through this material.
- With a semiconductor, there are too many electrons in the outermost shell for it to be a conductor, so it acts like an insulator. However; the conduction band is quite close; if we provide some external energy, some electrons will gain enough energy to make the jump from the valance and into the conduction band to become free. Therefore, this material can act as both an insulator or a conductor.

Semiconductor examples:

- Silicon
- Germanium
- Indium
- Boron
- Tellurium

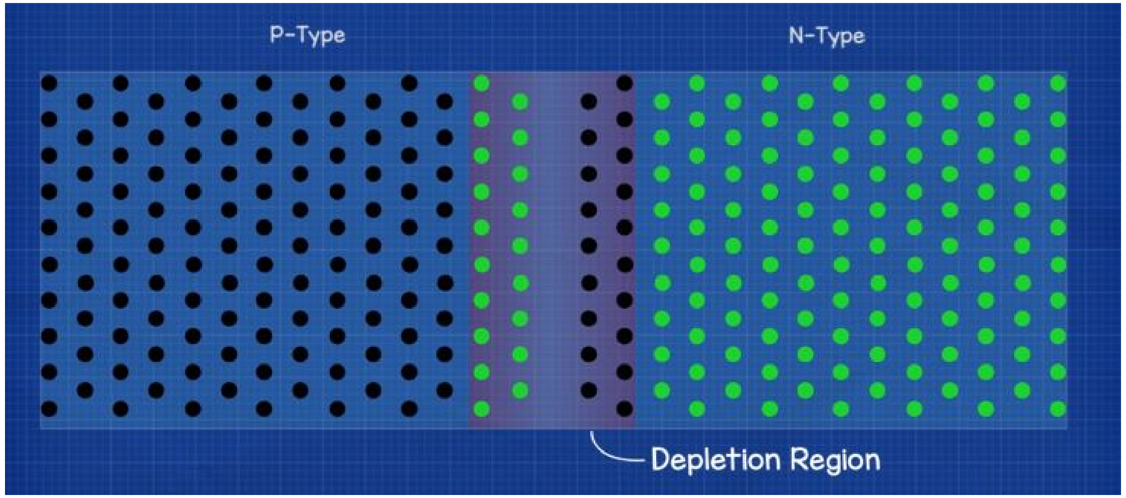
Semiconductor Material

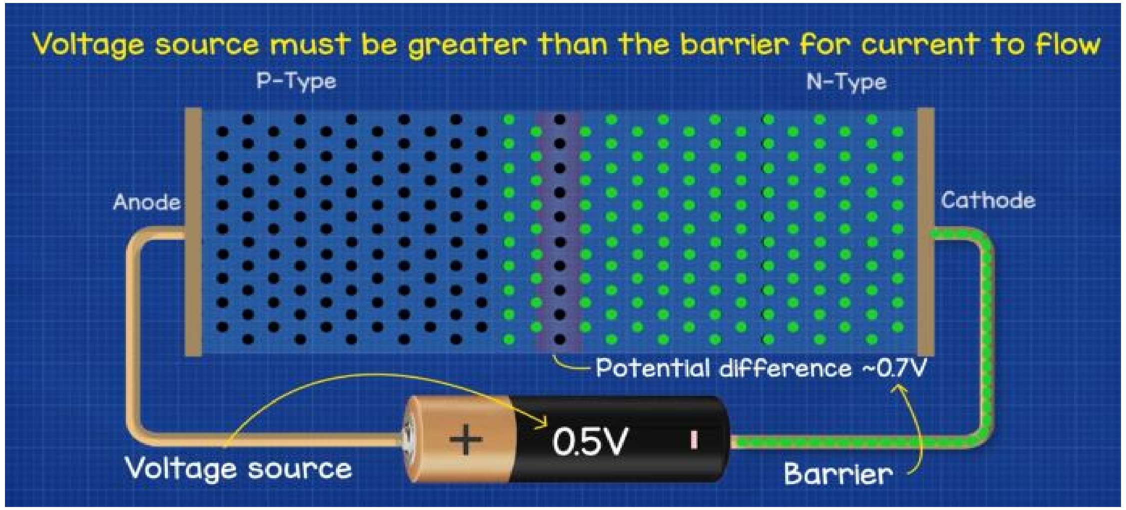




- Pure silicon has almost no free electrons, so what engineers do is dope the silicon with a small amount of other materials to change its electrical properties.
- N-type material such as phosphorus, it has 5 electrons in its valence shell. So as the silicon atoms are sharing electrons to get their desired 8, they don't need this extra one, so there's now extra electron in the material and these are therefore free to move.
- P-type material such as aluminium, it has only 3 electrons in its valence shell so it can't provide it's 4 neighbors with an electron to share, so one of them will have to go without. Therefore, there is a hole created where an electron can sit and occupy.

Depletion and

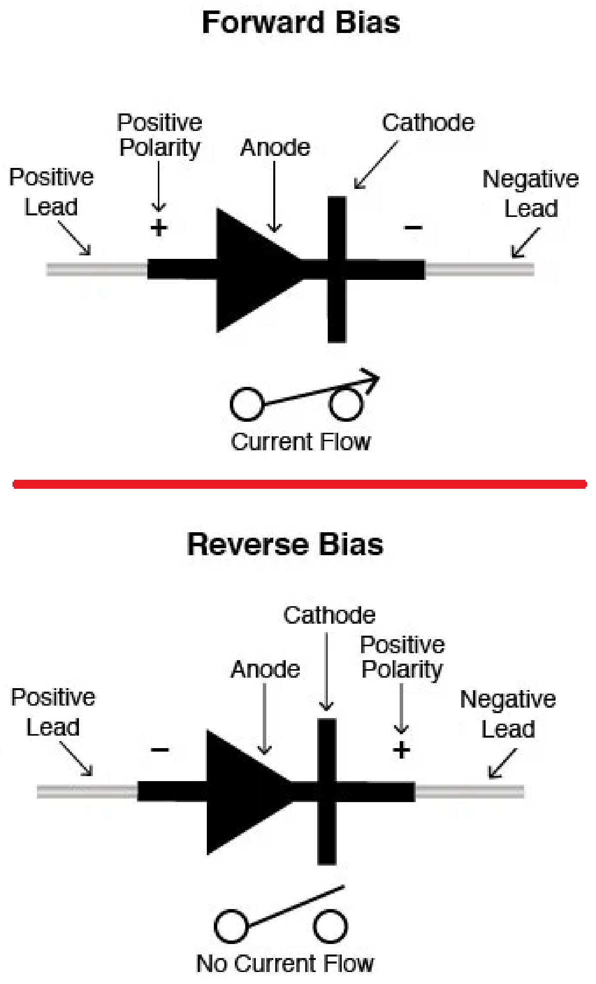




- The two materials join to form a P-N junction. At this junction we get what's known as a depletion region. In this region, some of the excess electrons from the N-type side will move over to occupy the holes in the P-type side. This migration will form a barrier with a buildup of electrons and holes on the opposite sides.
- When we connect a voltage source across the diode, with the anode (P-Type) connected to the positive and the cathode (N) connected to the negative, this will create a forward bias and allow current to flow. The voltage source has to be greater than the 0.7V (for Silicon, or 0.3V for Germanium) barrier otherwise the electrons can't make the jumper.

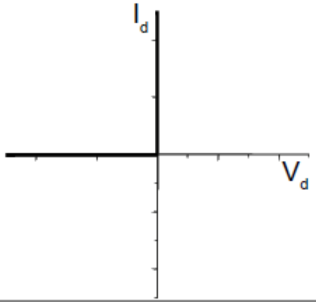
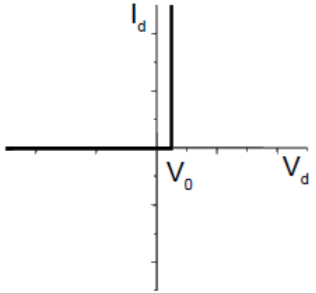
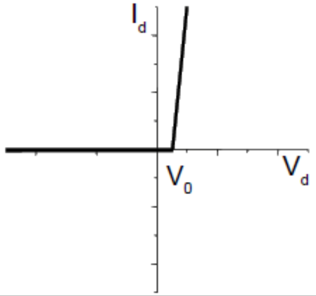
Semiconductor Diode

- A diode (PN) is an electronic component that directs the flow of electricity in a single direction.
- These are called "active components" and are basic components of semiconductors.
- They can regulate the flow of electricity, maintain a constant voltage, and extract signals from radio waves, etc.



Piecewise Linear Model

Table 6.1 Piecewise linear models for diodes

Model	Description	Graph of I versus V
"Ideal Diode" (The simplest model)	Either $V = 0$, $I > 0$ or $I = 0$, $V < 0$	
Ideal diode with "turn-on" voltage (Improves on the ideal diode if voltages encountered are less than or comparable to about 1 V)	Either $V = V_0$, $I > 0$ or $I = 0$, $V < V_0$ ($V_0 \approx 0.5$ V for typical semiconductor diodes, though somewhat larger for some special diodes such as LED's)	
Ideal diode with turn-on voltage and some resistance (Improves on the above by adding some diode resistance. Use if diode resistance is not negligible compared to others in the circuit)	Either $I = 0$, $V < V_0$ or $I = (V - V_0)/R_d$ if $V > V_0$ (R_d is an effective resistance for the diode. Its value depends on the "typical current" encountered)	

Analytic Model

$$I_d = I_0(\exp(V_d/\eta V_T) - 1)$$

$$V_T = \frac{T}{11600} = 0.026\,\mathrm{V\ at\ 300\,K}$$

- I_d is the current flowing throughout the diode in Amperes.
- I_o is the reverse saturation current in Amperes.
- V_d is the volt applied to the diode in Volts.
- Eta is the emission (or nonideality) coefficient (~1).
- V_T is the volt equivalent of temperature in Volts.
- T is the absolute temperature in Kelvin.

Ideal Diode Example

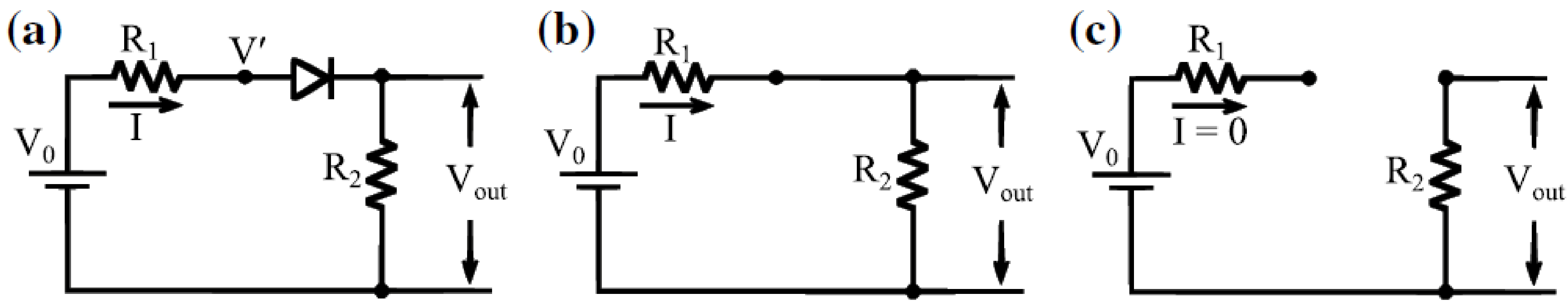


Fig. 6.4 The simple circuit in (**a**) is analyzed using the ideal diode model in (**b**) and (**c**). In (**b**) the diode is considered conducting and in (**c**) it is considered to be in reverse bias. Only one of (**b**) or (**c**) can be correct

Half-Wave Rectifier Example

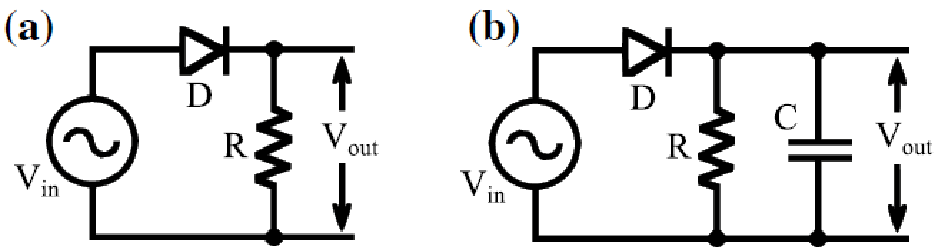


Fig. 6.5 (**a**) A simple half-wave rectifier, shown with a sinusoidal source, lets through only the positive part of the sine wave. In (**b**) the output is filtered by a capacitor so it will be closer to being constant in time

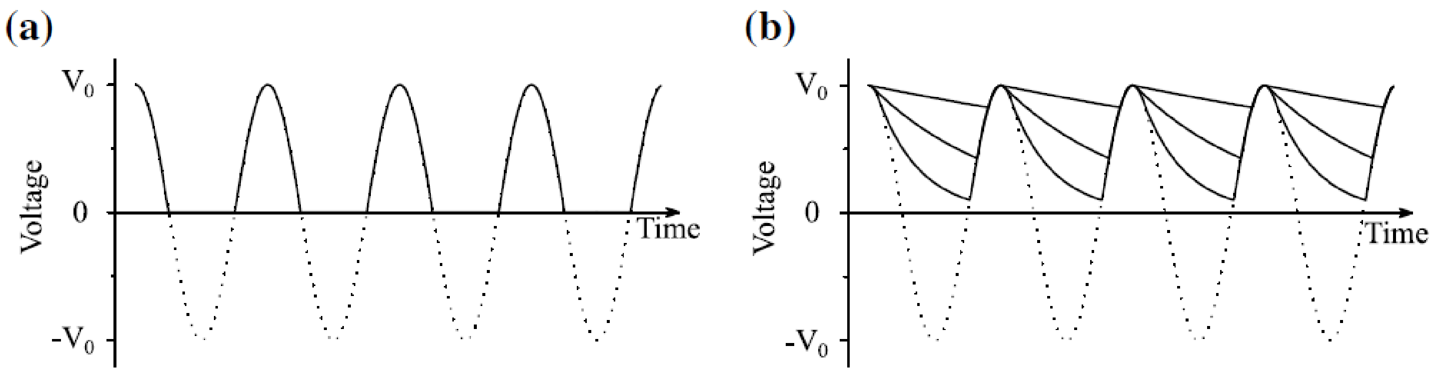


Fig. 6.6 The output of the circuits of Fig. 6.5a, b respectively. In (**b**) traces for three different capacitance values are shown. The larger the capacitance, the less droop will occur between maxima

Full-Wave Rectifier Example (1)

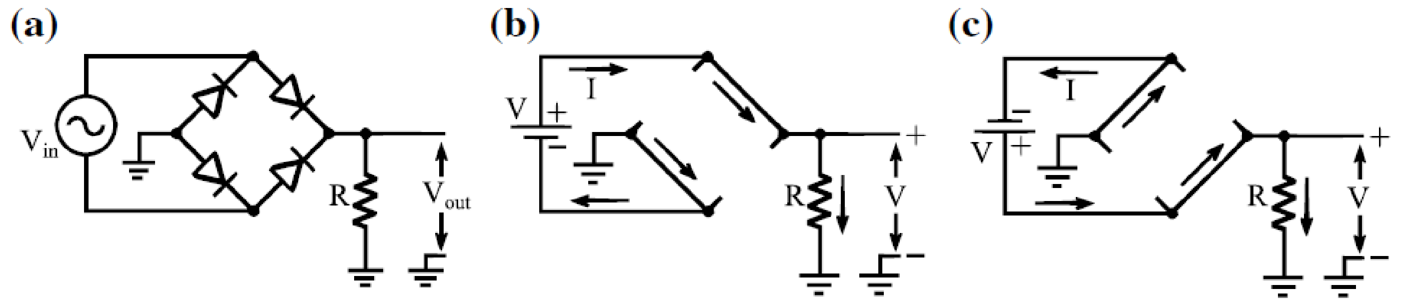


Fig. 6.12 The diode-bridge full-wave rectifier circuit shown at (**a**) is analyzed using the ideal diode model in (**b**) and (**c**)

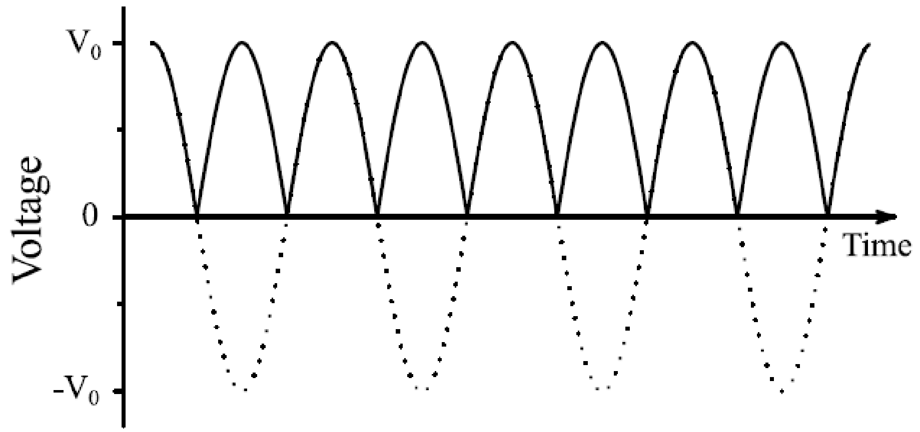


Fig. 6.13 The output from the circuit of Fig. 6.12a (solid) compared to the input (dotted)

Full-Wave Rectifier Example (2)

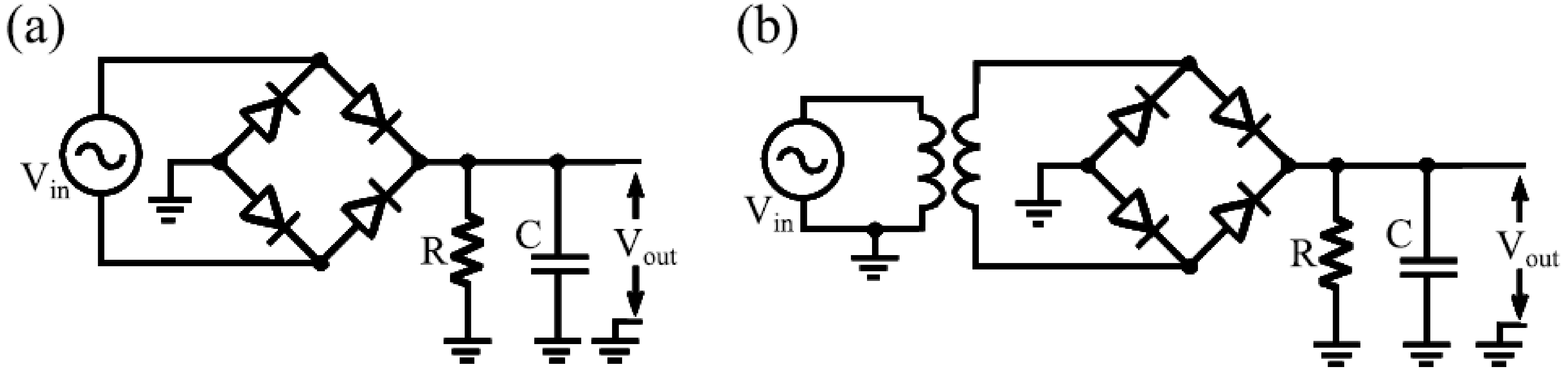


Fig. 6.14 (**a**) A capacitor is added to the full-wave rectifier to smooth the output. A common implementation uses a transformer on the input, as shown in (**b**), that can scale the voltage and eliminate potential problems with the ground connections

Voltage-Limiting Circuit Example

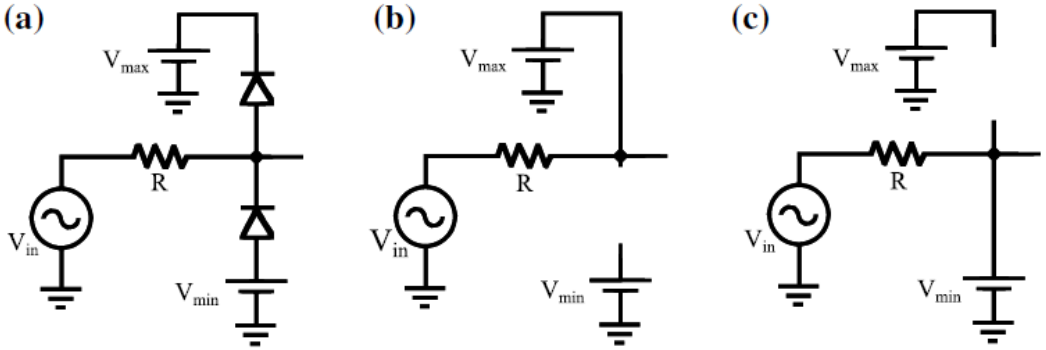


Fig. 6.7 A limiting circuit shown in (**a**) is analyzed using the ideal diode model in (**b**) and (**c**). If the input exceeds V_{max} or gets smaller than V_{min}, the corresponding diode conducts

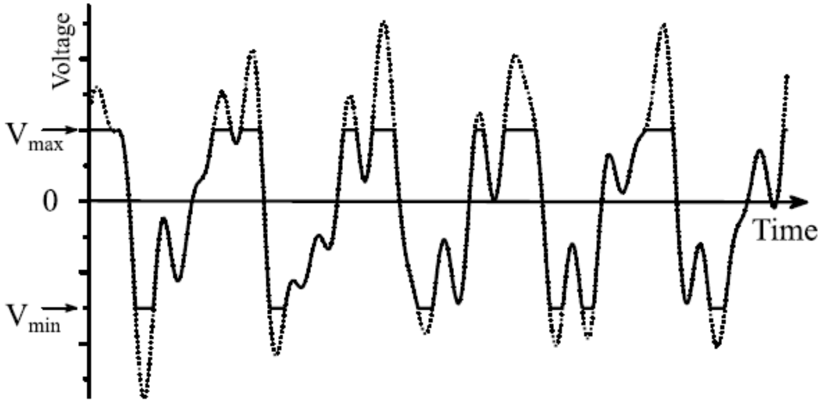


Fig. 6.8 An example showing the effects of a limiting circuit on a time-dependent signal. The original signal is shown dotted, while the output of the limiter is solid

Voltage-Clamping Circuit Example

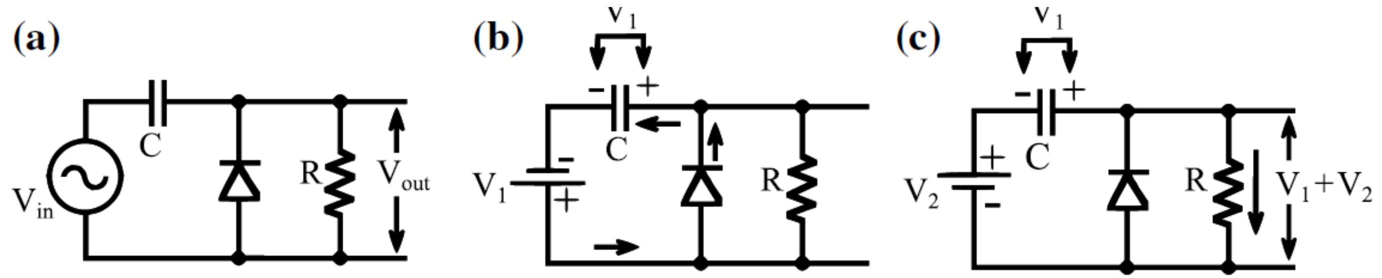


Fig. 6.9 The diode clamp circuit in (**a**) is analyzed in (**b**) and (**c**) for a negative input followed by a positive input respectively

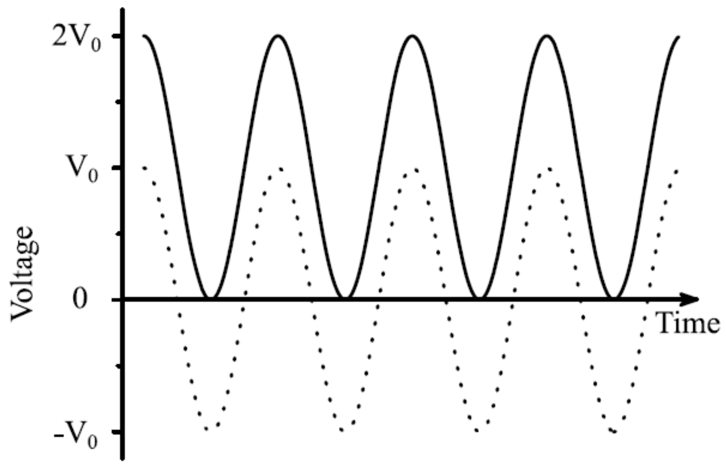
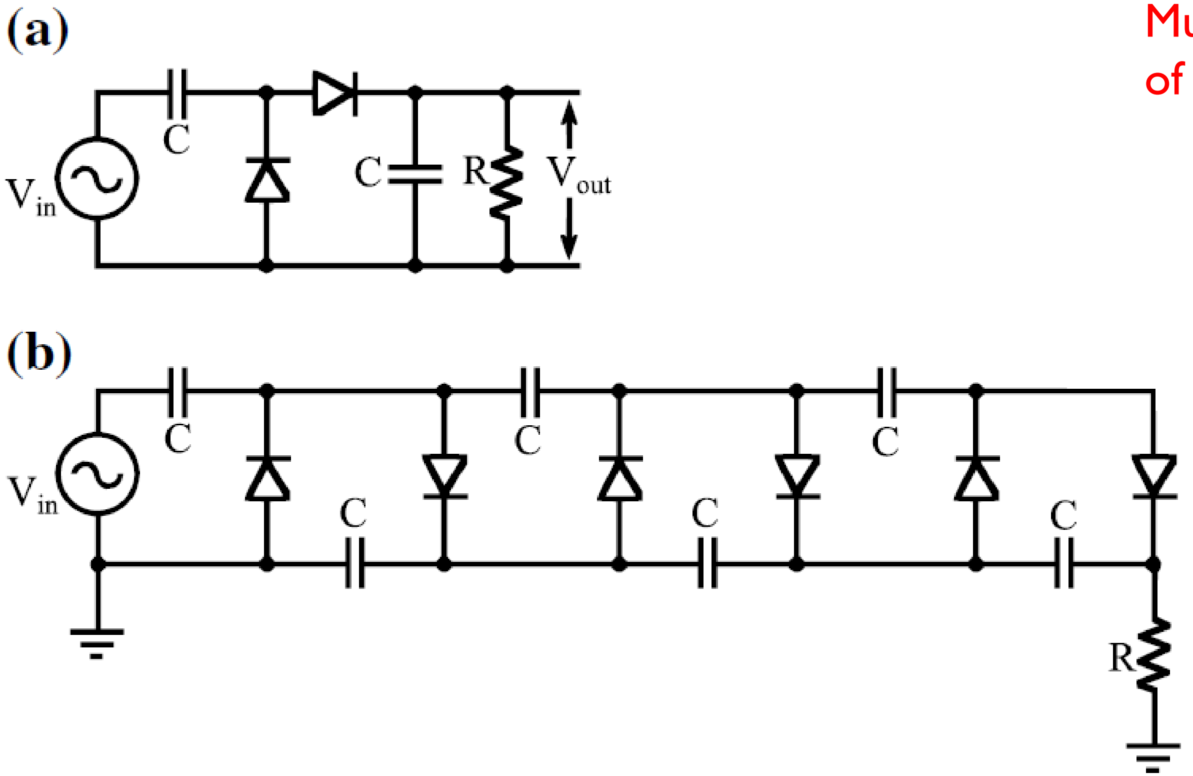


Fig. 6.10 The output from the diode clamp of Fig. 6.9a (solid) compared to the input (dotted) for a sinusoidal source

Shifting DC level of the voltage.

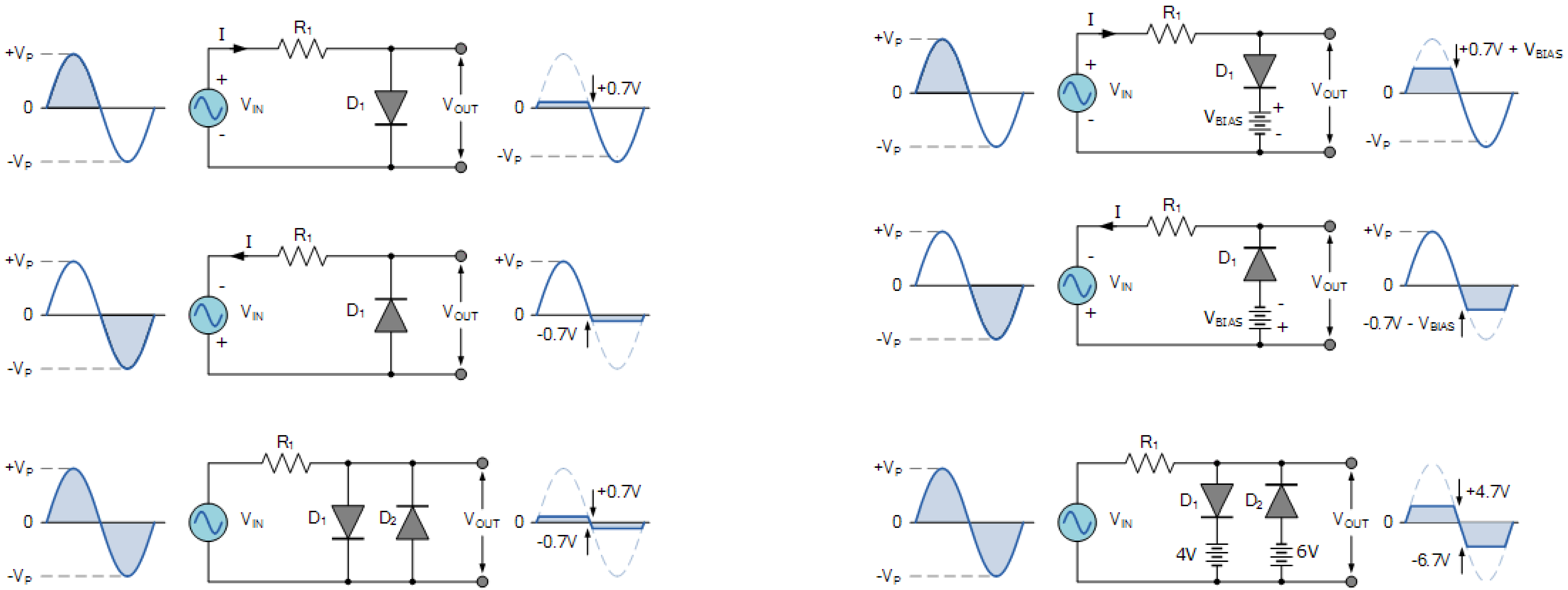
Voltage-Doubling Circuit Example



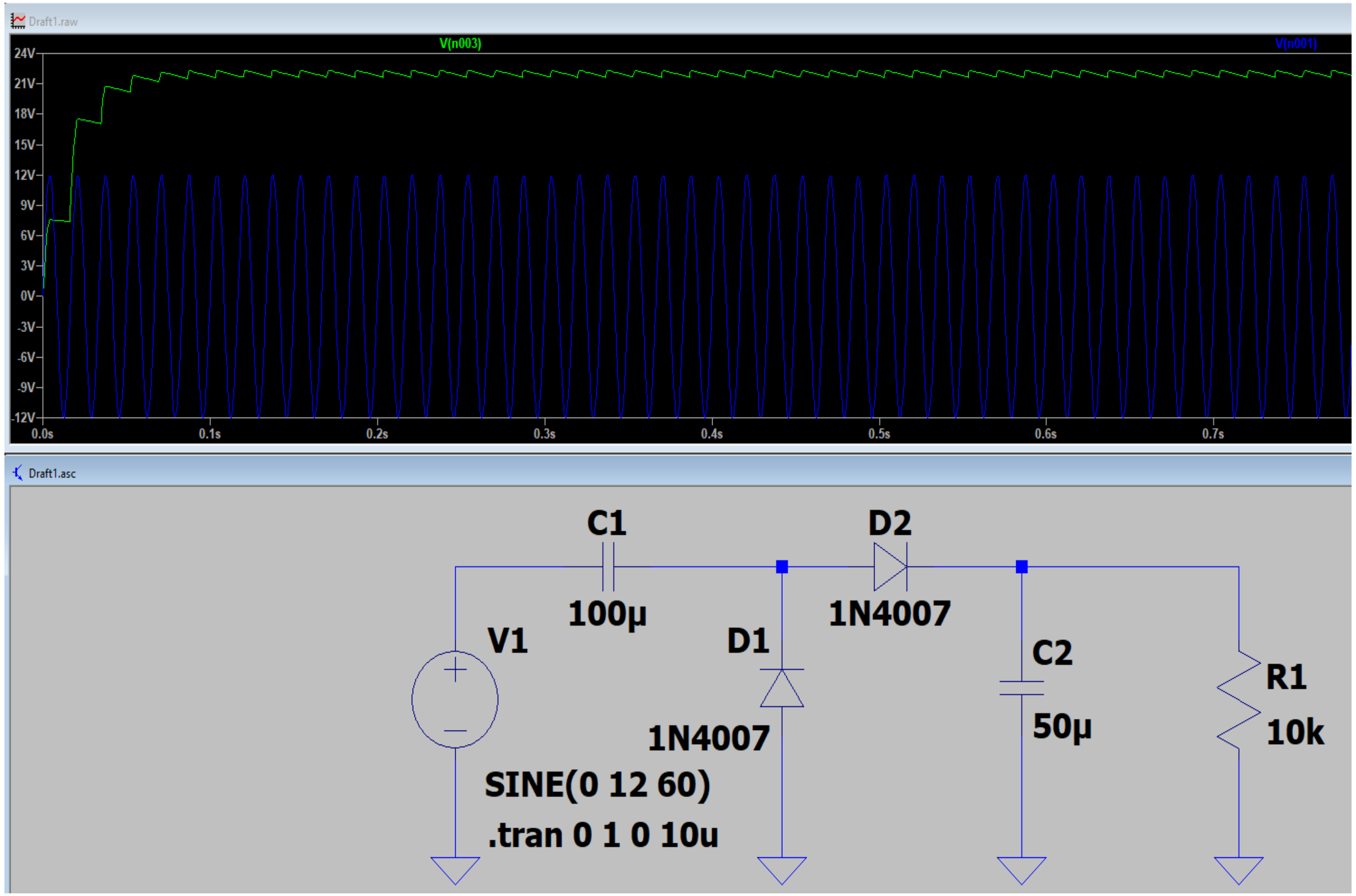
Multiplying max level of the voltage.

Fig. 6.11 A simple voltage doubler is shown in (**a**). The idea can be extended to achieve very high voltages, such as shown in (**b**)

Clipping Circuits



LTS: Left to Students (Voltage Doubler)




```
* Draft1.asc
V1 N001 0 SINE(0 12 60)
C1 N002 N001 100µ
D1 0 N002 1N4007
D2 N002 N003 1N4007
C2 N003 0 50µ
R1 N003 0 10k
.model D D
.lib standard.dio
.tran 0 1 0 10u
.end
```

Analyze all the circuit given in this lecture using LTspice!

Thanks for listening ☺

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