

Half-Wave and Full-Wave Diode Rectifiers

▼ Introduction

Rectifiers convert alternating current to direct current. This worksheet calculates the response of both a half-wave and a full-wave diode rectifier circuit with a single capacitor filter in response to a sinusoidal input.

First, we define and plot the response of an ideal diode. Then, we define, solve and plot the response of differential equations that describe half-wave and full-wave rectifiers.

Reference:

Adapted from [this Maple worksheet](#) by Tony Vaughan.

```
> restart :
with( plots ) :
with( ScientificConstants ) :

> dark_gridlines :=
  background = ColorTools:-Color( "RGB", [ 0, 0, 0 ] )
  , color = white
  , thickness = 2
  , axes = frame
  , axis = [ gridlines = [ 10, linestyle = dot, color = ColorTools:-Color( "RGB", [ 0.5, 0.5, 0.5 ] ) ] ]
  , font = [ Consolas ]
  , labelfont = [ Consolas ]
  , titlefont = [ Consolas, 16 ]
  , size = [ 400·1.78, 400 ]
  , labeldirections = [ horizontal, vertical ] :
```

▼ Parameters

Capacitance and resistance of half-wave rectifier

```
> C := 2200·10-6 :
  RL := 20 :
```

Temperature

```
> T := 293 :
```

Diode saturation current

> $I_0 := 10.0^{-9}$:

Emission coefficient (1 for germanium, 2 for silicon)

> $N := 2$:

Input voltage to circuit

> $f := 60.0$:

Boltzman constant

> $K := \text{evalf}(\text{Constant}('k'))$

$$K := 1.38064851010^{-23} \quad (2.1)$$

Charge on an electron

> $Q := \text{evalf}(\text{Constant}('e'))$

$$Q := 1.60217662010^{-19} \quad (2.2)$$

▼ Ideal Diode

Thermal voltage

> $vt := \frac{KT}{Q}$

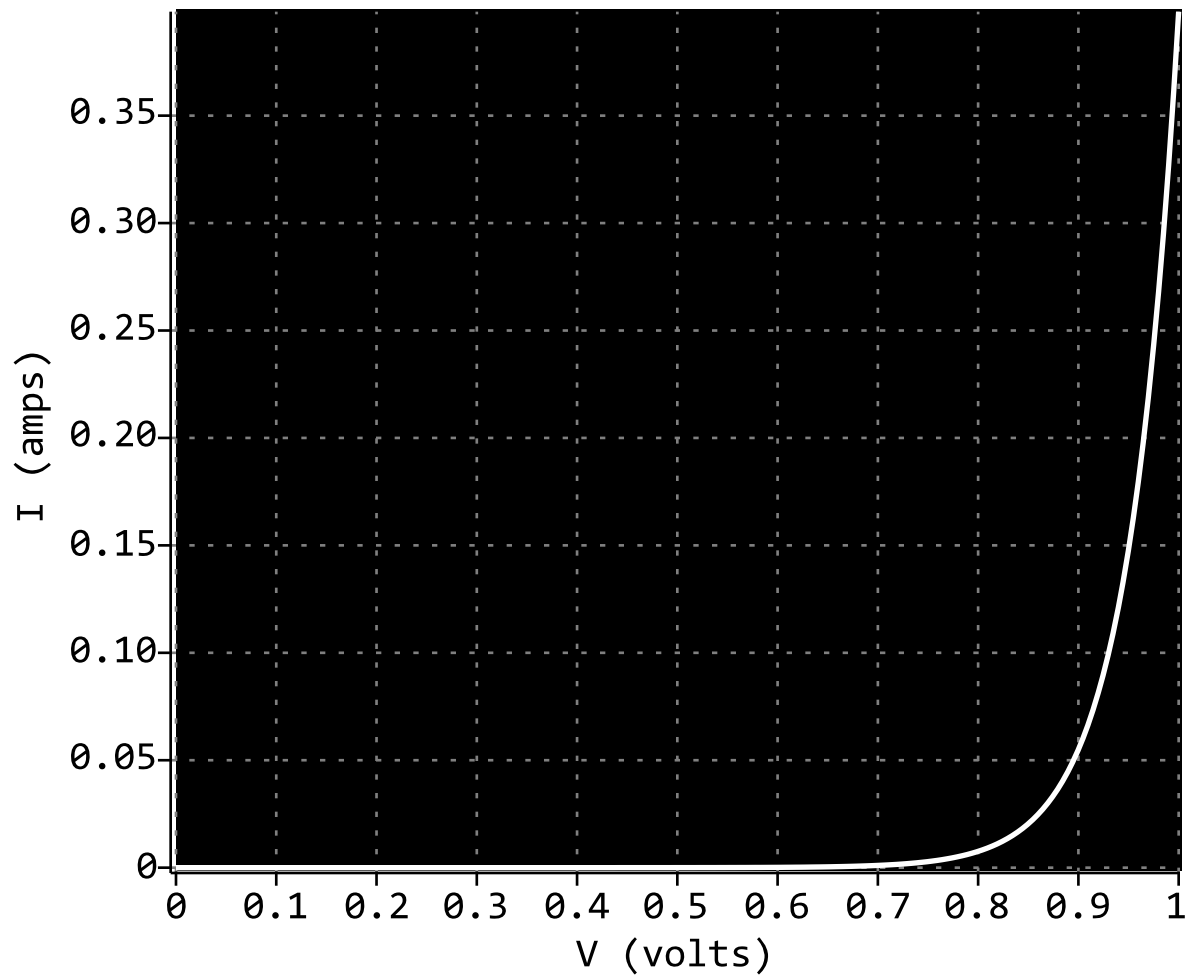
$$vt := 0.02524877772 \quad (3.1)$$

Ideal diode equation

> $\text{idea_diode} := V \rightarrow I_0 \left(e^{\frac{V}{vt N}} - 1 \right) :$

> $\text{plot}(\text{idea_diode}(V), V = 0 .. 1, \text{labels} = ["V \text{ (volts)", "I \text{ (amps)"}], \text{title} = "Ideal Silicon Diode", \text{dark_gridlines})$

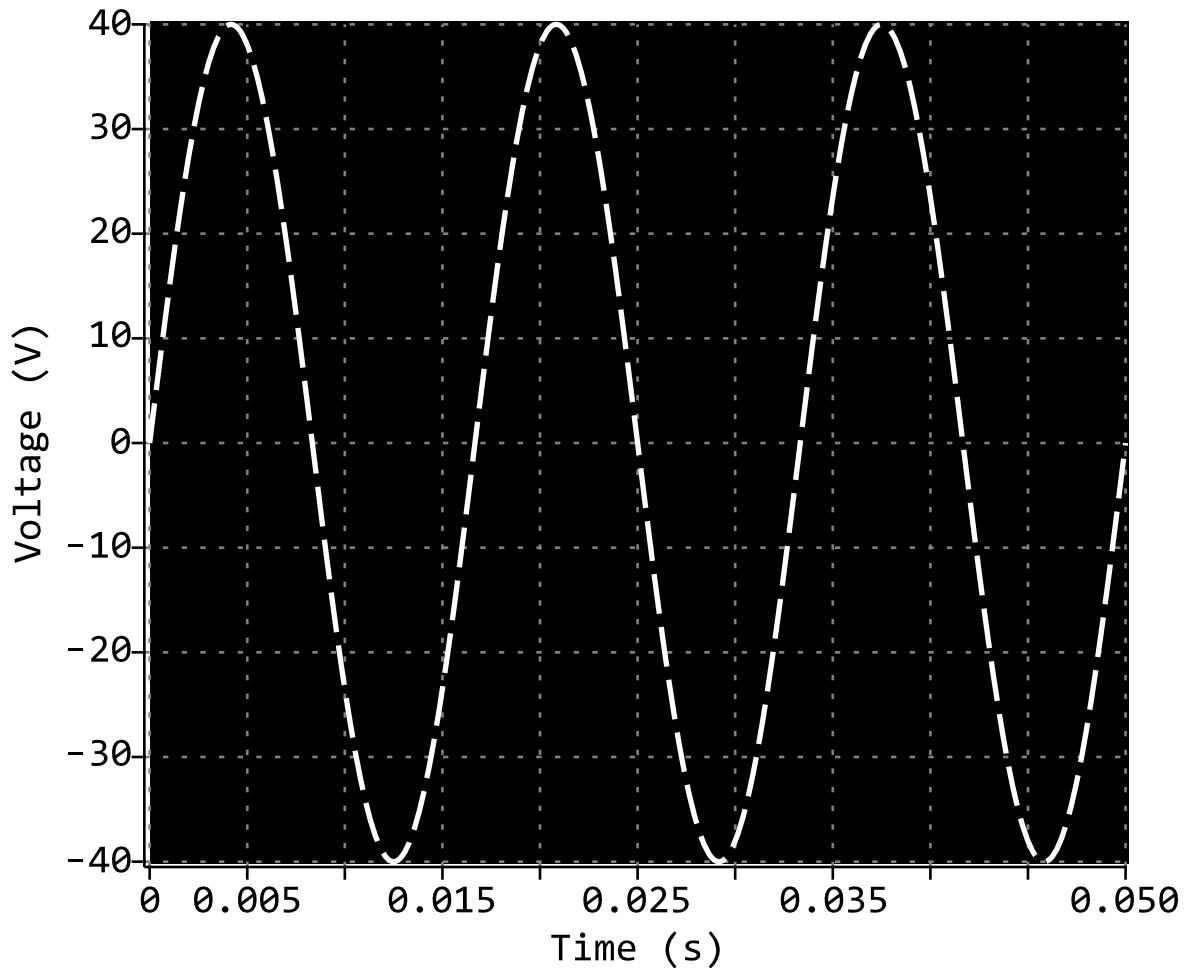
Ideal Silicon Diode



▼ Input Voltage

- > $V_{input} := 40 \sin(f \cdot 2 \cdot \pi \cdot t) :$
- > $p1 := plot(V_{input}, t = 0 .. 0.05, labels = ["Time (s)", "Voltage (V)"], title = "Input Voltage", dark_gridlines, linestyle = dash)$

Input Voltage



▼ Half-Wave Rectifier

This differential equation describes the half-wave rectifier circuit with a single capacitor filter, where i_1 is the diode current.

$$> \text{hw_rectifier_DE} := C \frac{d}{dt} V_t(t) + \frac{V_t(t)}{R_L} - i_1 = 0 :$$

$$> \text{hw_rectifier_DE} := \text{subs}(i_1 = \text{idea_diode}(V_{\text{input}} - V_t(t)), \text{hw_rectifier_DE})$$

$$\text{hw_rectifier_DE} := \frac{11 \frac{d}{dt} V_t(t)}{5000} + \frac{V_t(t)}{20} - 1.00000000010^{-9} e^{792.1175520 \sin(376.9911184 t) - 19.80293880 V_t(t)} + 1.00000000010^{-9} = 0 \quad (5.1)$$

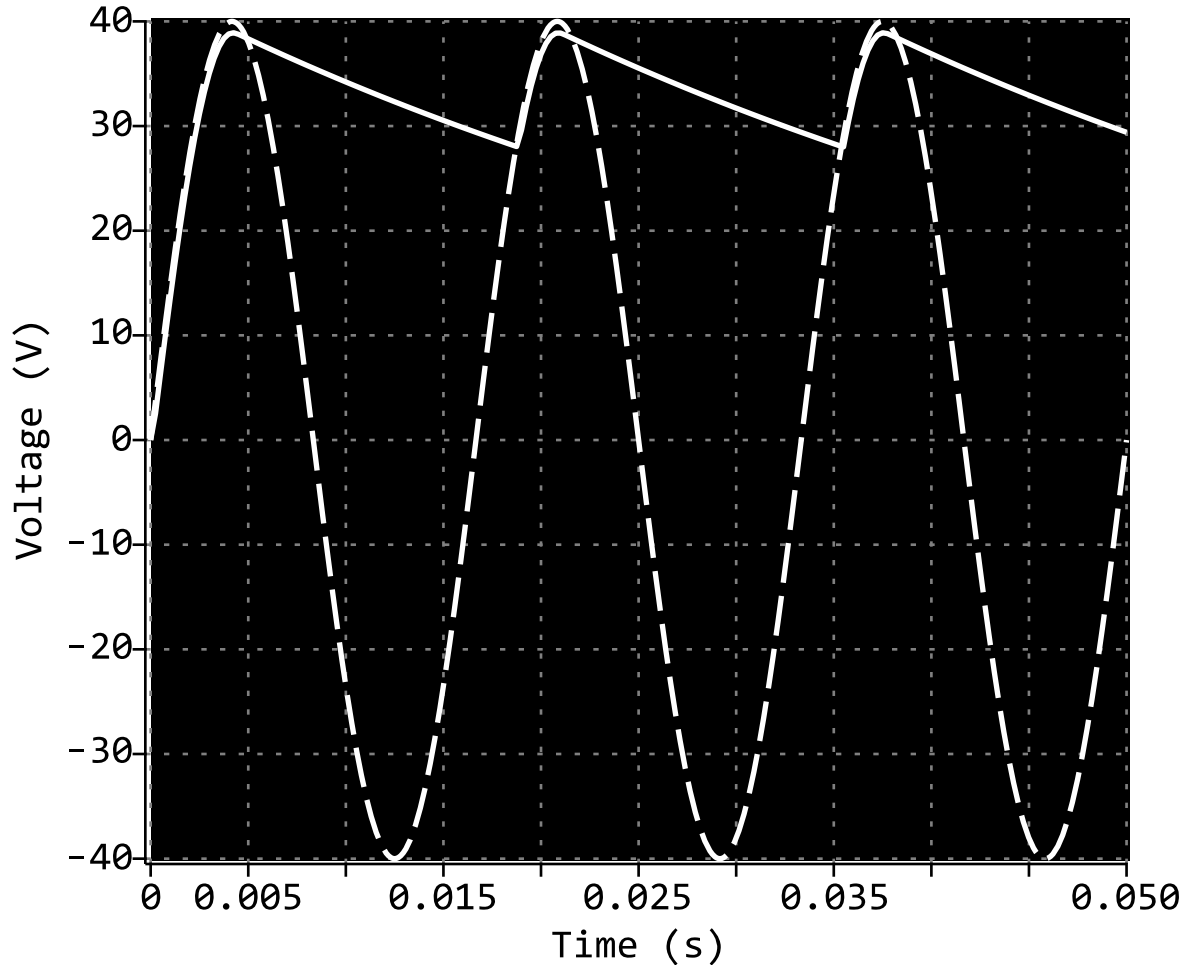
This non-linear first order differential equation describes the circuit.

$$> \text{res} := \text{dsolve}(\{\text{hw_rectifier_DE}, V_t(0) = 0\}, \text{numeric})$$

$$\text{res} := \text{proc}(x_rkf45) \dots \text{end proc} \quad (5.2)$$

```
> p2 := odeplot( res, [t, Vt(t)], 0..0.05, labels = ["Time (s)", "Voltage (V)"], title
= "Output Voltage of Half-Wave Rectifier", dark_gridlines) :
> display( p2, p1)
```

Output Voltage of Half-Wave Rectifier



▼ Full-Wave Rectifier

This differential equation describes the full-wave rectifier circuit with a single capacitor filter, where i_1 and i_2 are the diode currents.

```
> fw_rectifier_DE := C * d/dt Vt(t) + Vt(t)/RL - i1 - i2 = 0 :
```

```
> fw_rectifier_DE := subs( { i1 = idea_diode( Vinut - Vt(t) ), i2 = idea_diode( -Vinut
- Vt(t) ) }, fw_rectifier_DE)
```

$$fw_rectifier_DE := \frac{11 \frac{d}{dt} Vt(t)}{5000} + \frac{Vt(t)}{20} - 1.000000000 \cdot 10^{-9} e^{792.1175520 \sin(376.9911184 t) - 19.80293880 Vt(t)} + 2.000000000 \cdot 10^{-9} \quad (6.1)$$

$$-1.00000000010^{-9} e^{-792.1175520 \sin(376.9911184 t) - 19.80293880 V_t(t)} = 0$$

```
> res := dsolve( {fw_rectifier_DE, Vt(0) = 0}, type = numeric)
```

```
res := proc(x_rkf45) ... end proc
```

(6.2)

```
> p3 := odeplot( res, [t, Vt(t)], 0..0.05, labels = ["Time (s)", "Voltage (V)"], title
= "Output Voltage of Full-Wave Rectifier", dark_gridlines) :
```

```
> display( p3, p1)
```

Output Voltage of Full-Wave Rectifier

