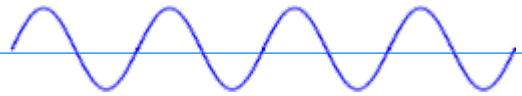
Rectifier (H.1)

20170407

Rectifiers



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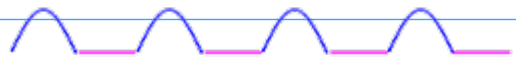


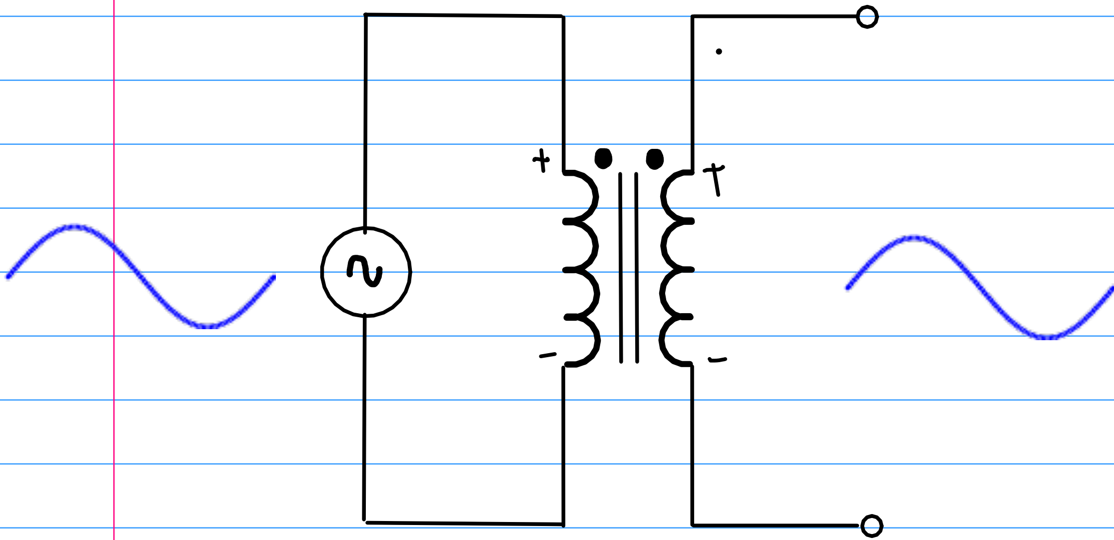
half wave rectifier

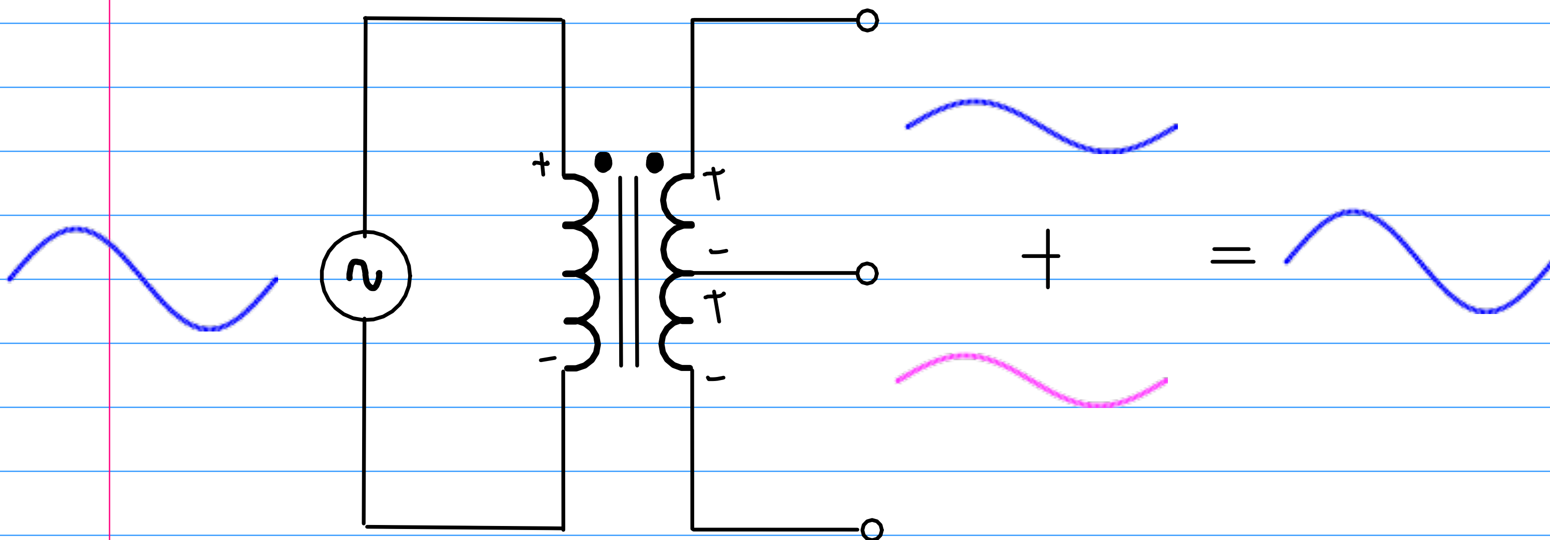
full wave rectifier

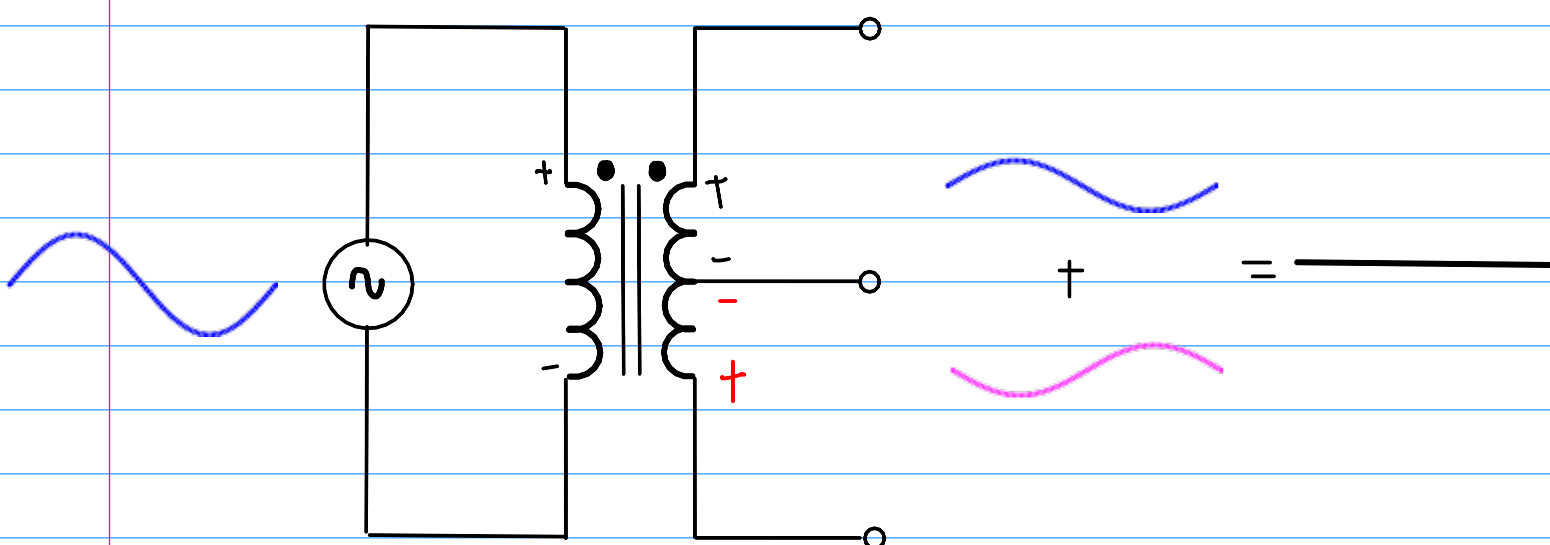
① Tapped Transformer

② Bridge

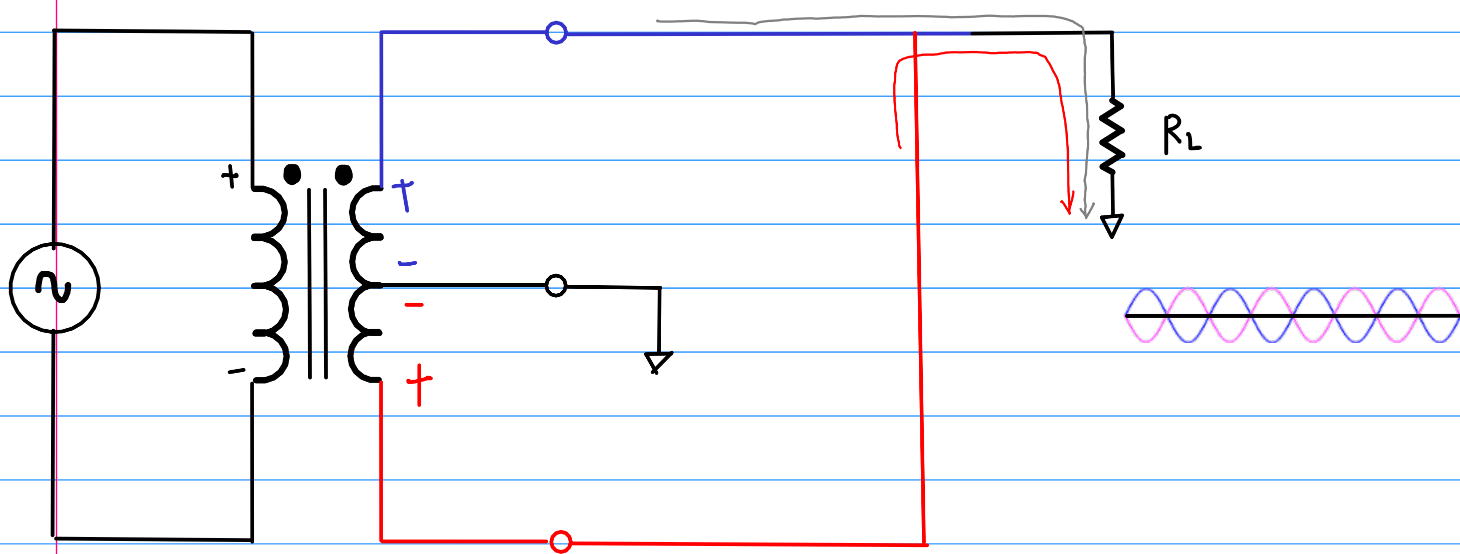
Tapped Transformer

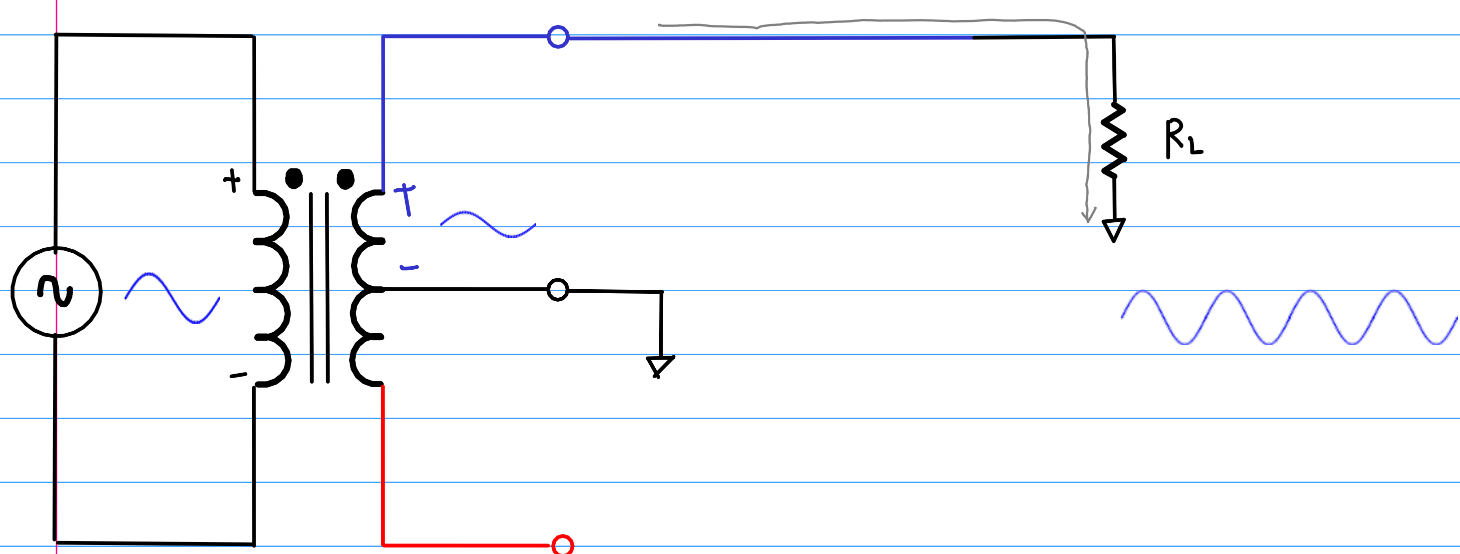


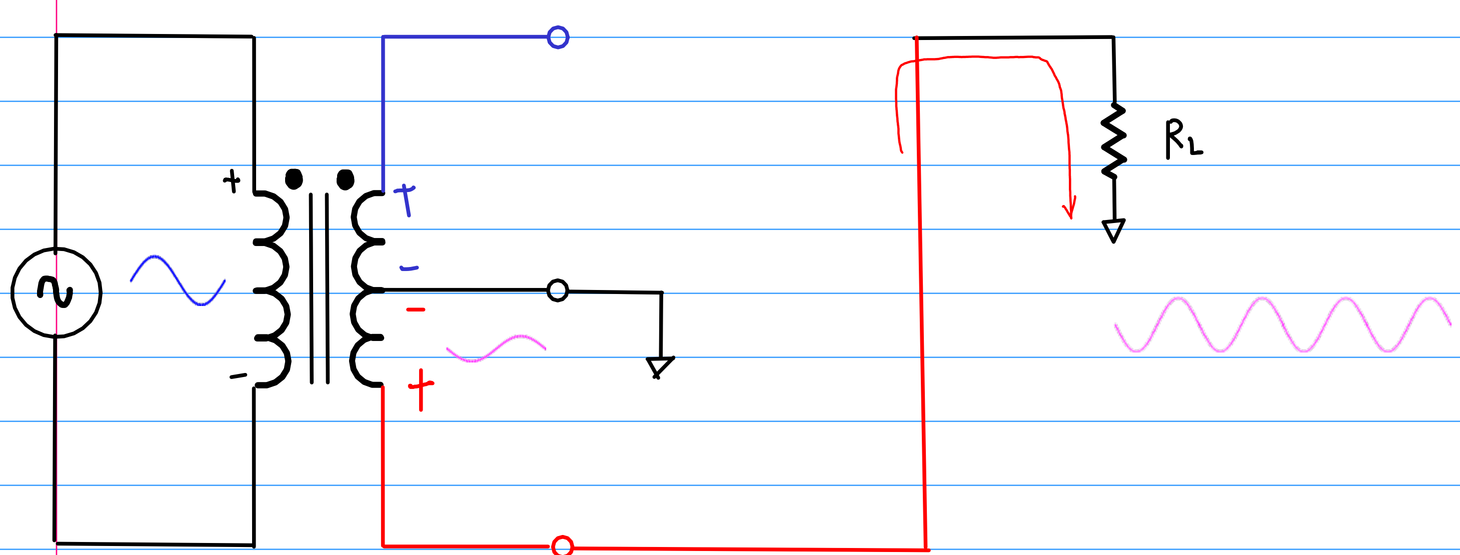


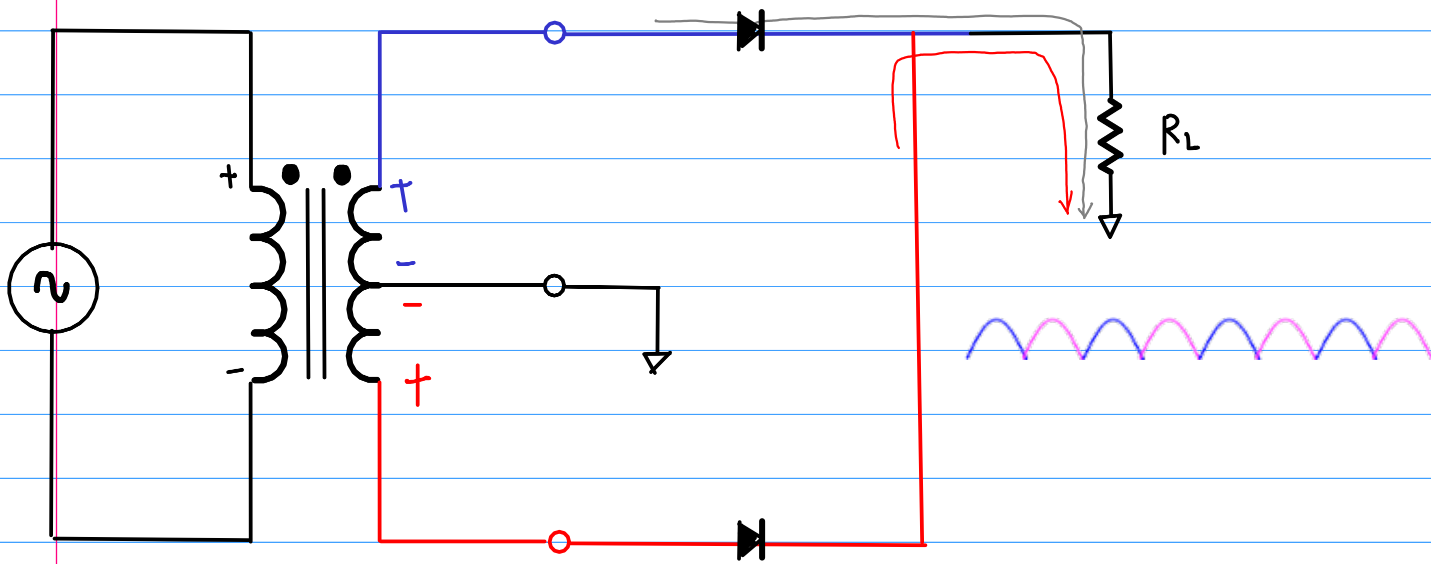


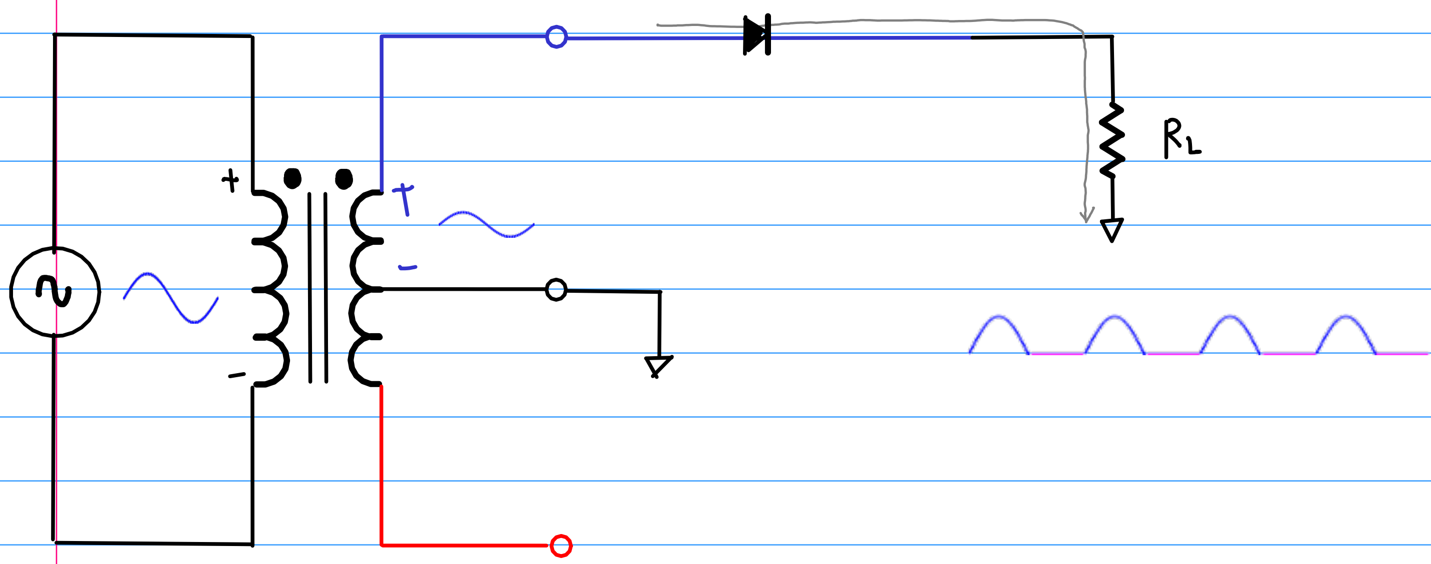
Supperposition

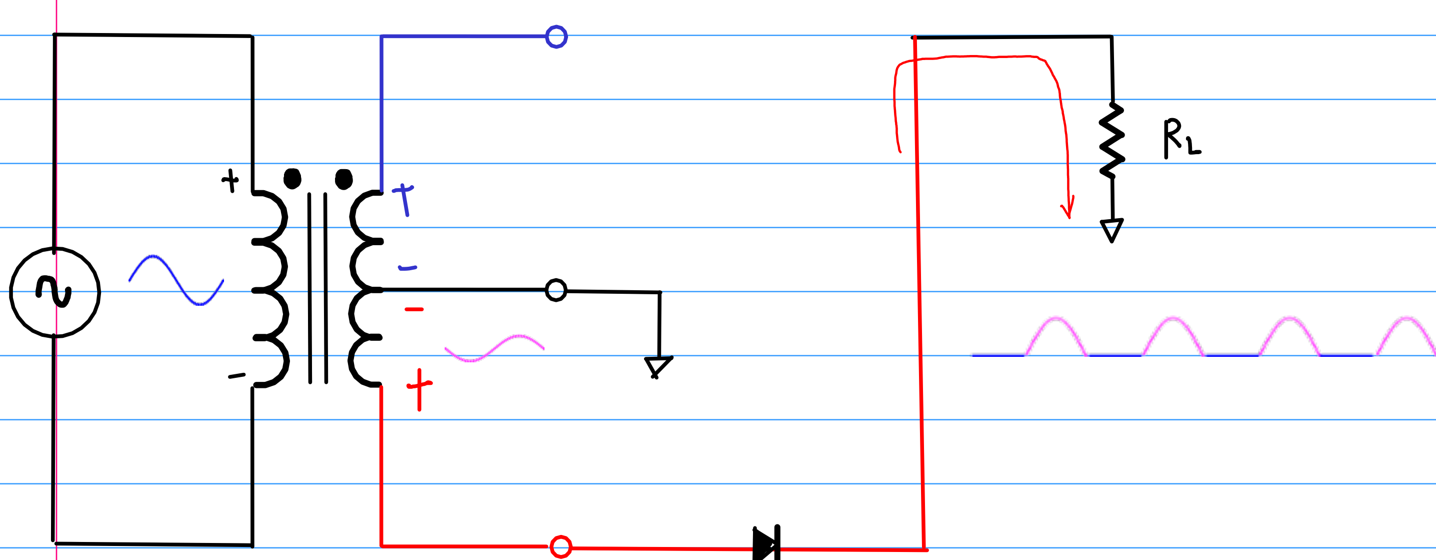




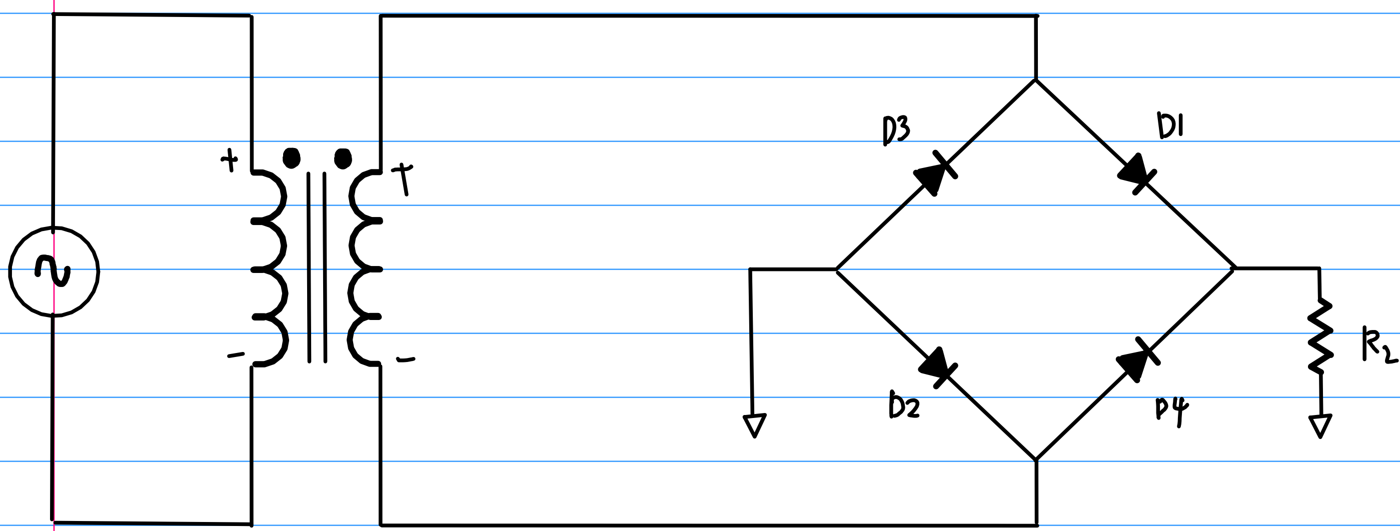


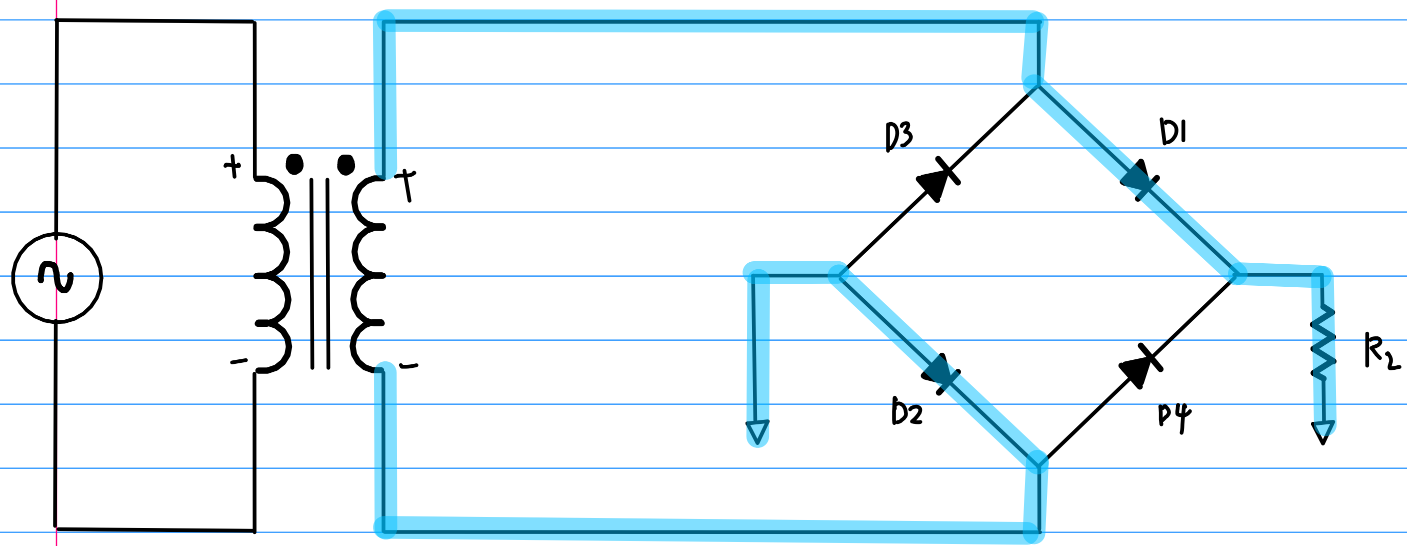

RL


RL

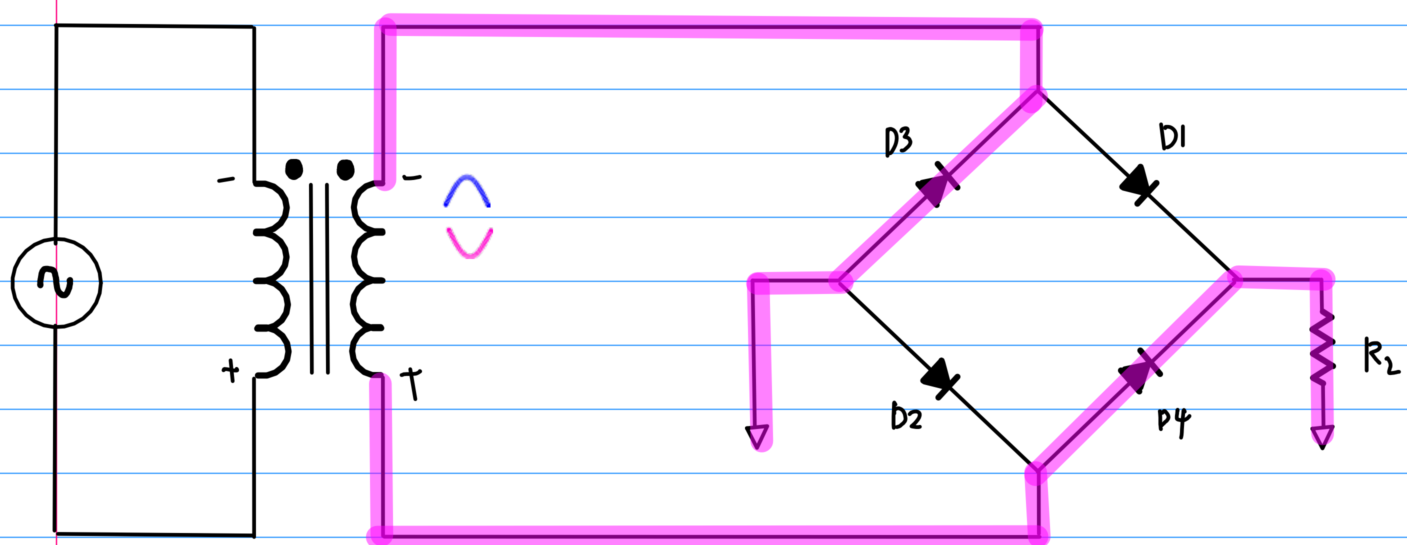

RL

Bridge Rectifier

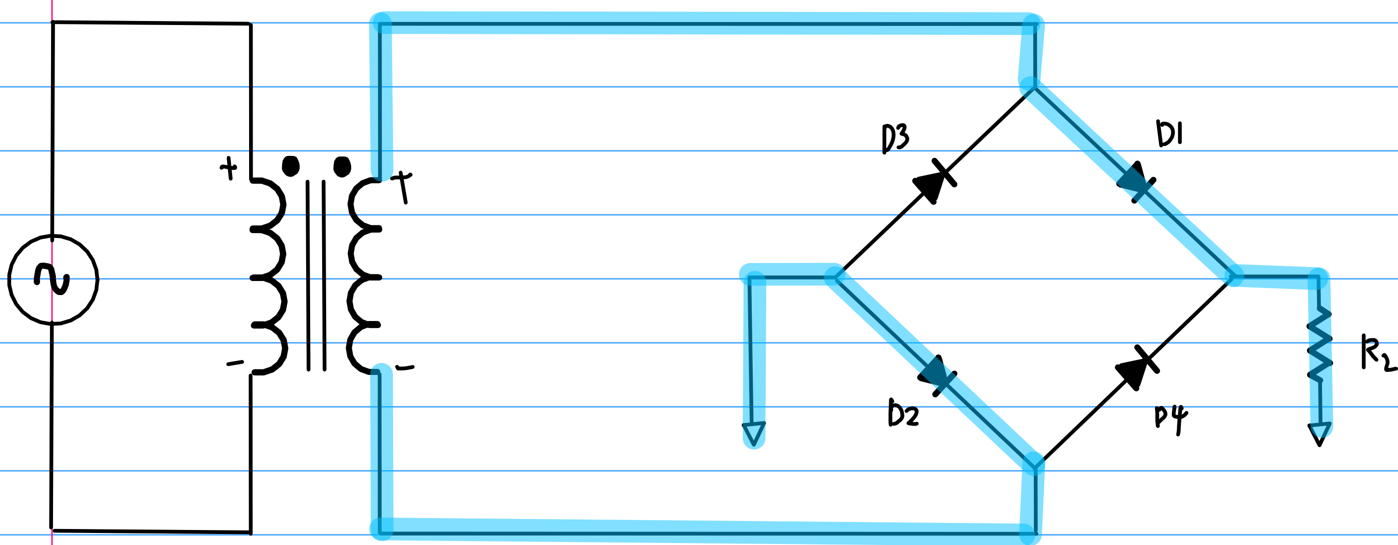


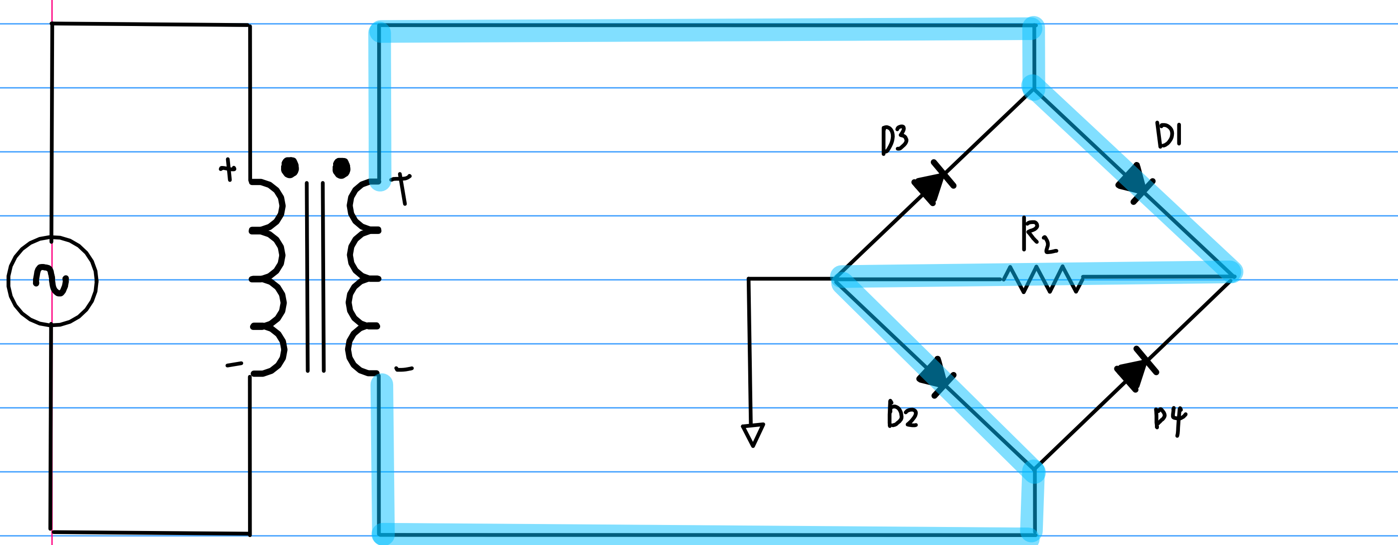


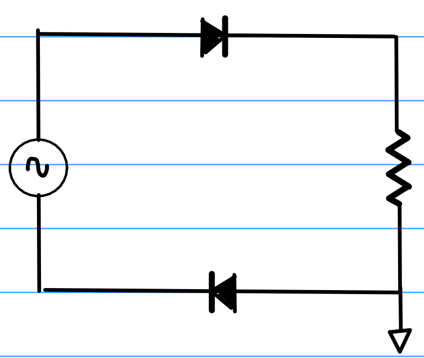
+
-
D3
D1
D2
D4
R_2

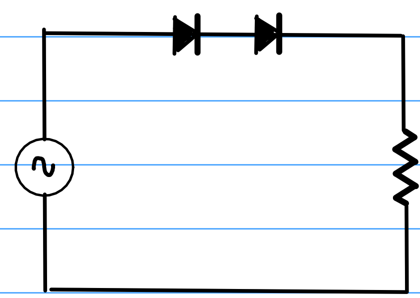


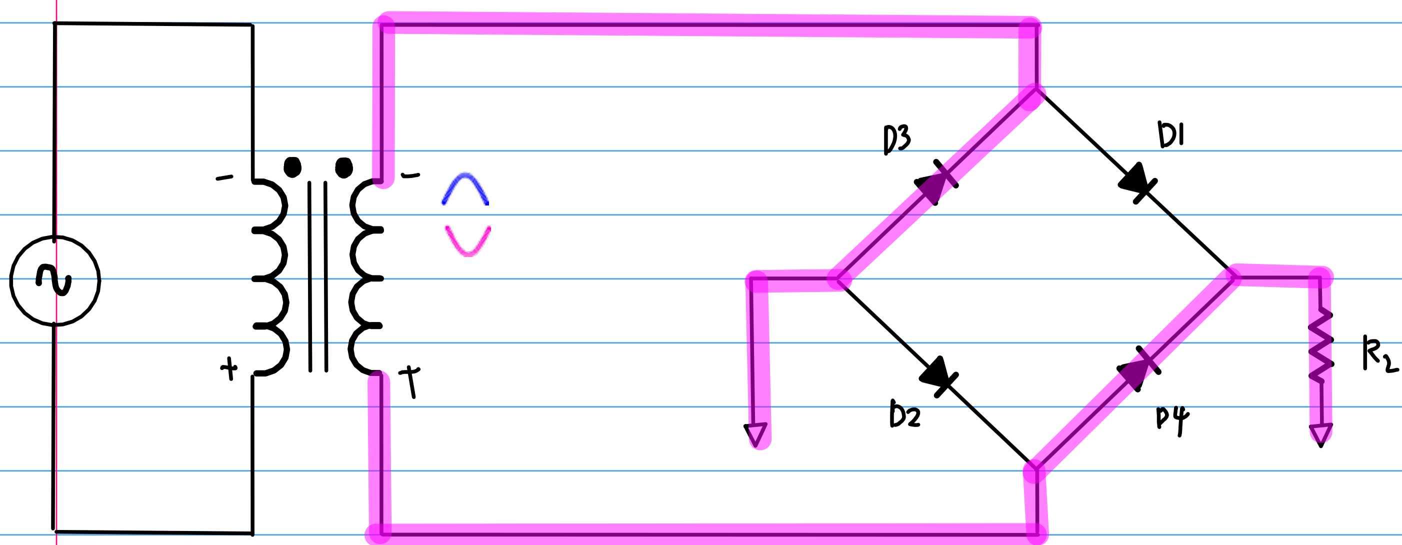
-
+
D3
D1
D2
D4
R_2

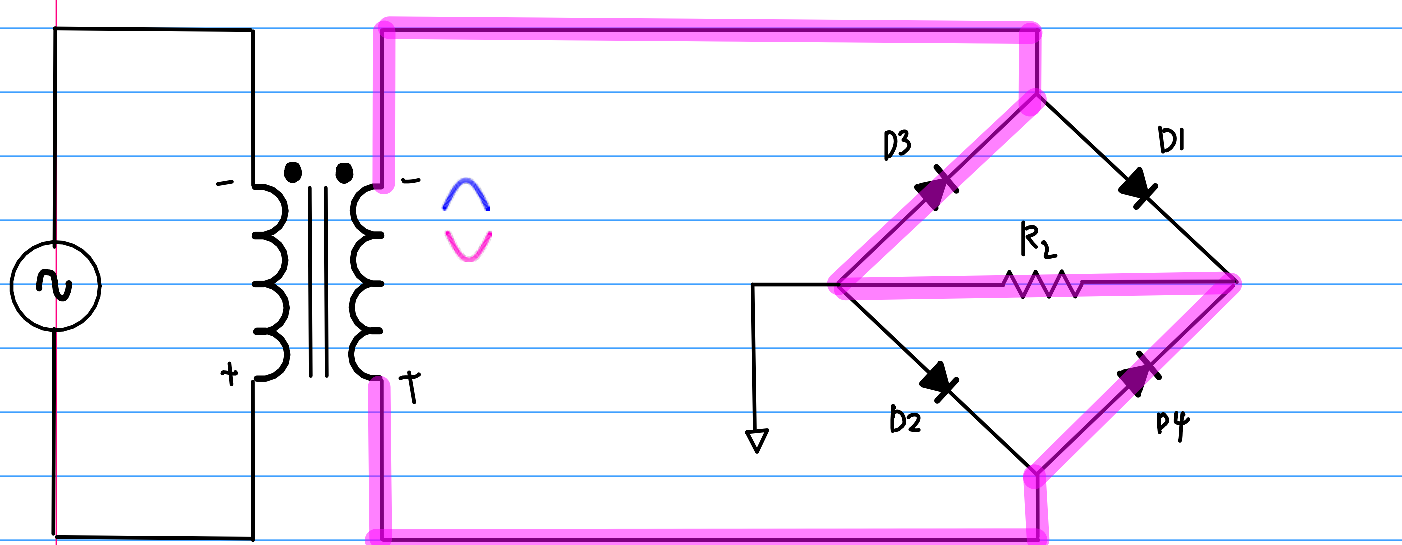

+
-
D3
D1
D2
D4
R2

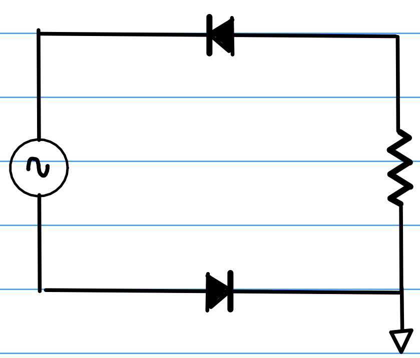

+
-
D3
D1
R2
D2
D4

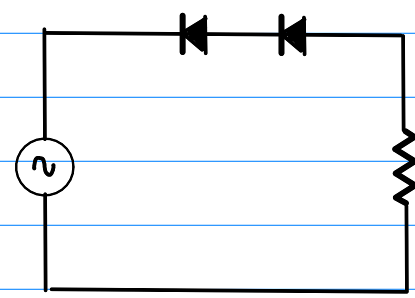




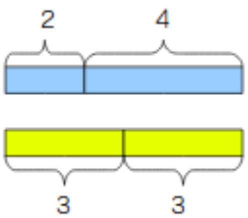

D3
D1
D2
D4
R2


D3
D1
R2
D2
D4





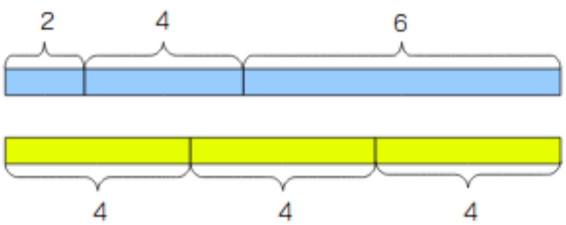
Arithmetic Mean – Example



• same length

$$(2+4)=(3+3)=2\cdot 3=2\cdot A$$

Arithmetic Mean: A = 3



• same length

$$(2+4+6)=(4+4+4)=3\cdot 4=3\cdot A$$

Arithmetic Mean: A = 4

Geometric Mean

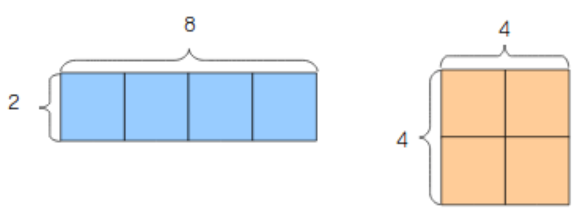
2 elements $\{a, b\}$ $\quad G = \sqrt{a \cdot b}$ $\quad (a > 0,\ b > 0)$

3 elements $\{a, b, c\}$ $\quad G = \sqrt[3]{a \cdot b \cdot c}$ $\quad (a > 0,\ b > 0,\ c > 0)$

n elements $\{a_1, a_2, \dots, a_n\}$ $\quad G = \sqrt[n]{a_1 \cdot a_2 \cdots a_n} = \left(\prod_{i=1}^{n} a_i\right)^{\frac{1}{n}}$

$(a_i > 0)$

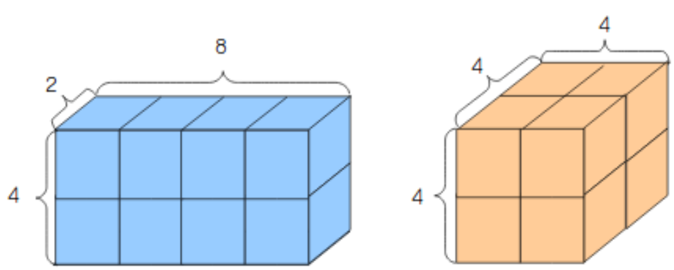
Geometric Mean — Example



$$(2 \cdot 8) = (4 \cdot 4) = 4^2 = G^2$$

Geometric Mean: G = 4

- same area



$$(2 \cdot 4 \cdot 8) = (4 \cdot 4 \cdot 4) = 4^3 = G^3$$

Geometric Mean: G = 4

- same volume

Root Mean Square

The RMS value of a set of values (or a continuous-time waveform) is the square root of the arithmetic mean of the squares of the values, or the square of the function that defines the continuous waveform. In Physics, the rms current is the "value of the direct current that dissipates power in a resistor."

In the case of a set of *n* values $\{x_1, x_2, \ldots, x_n\}$, the RMS

$$x_{\text{rms}} = \sqrt{\frac{1}{n}\left(x_1^2 + x_2^2 + \cdots + x_n^2\right)}.$$

The corresponding formula for a continuous function (or waveform) *f(t)* defined over the interval $T_1 \leq t \leq T_2$ is

$$f_{\text{rms}} = \sqrt{\frac{1}{T_2 - T_1}\int_{T_1}^{T_2} [f(t)]^2 \, dt},$$

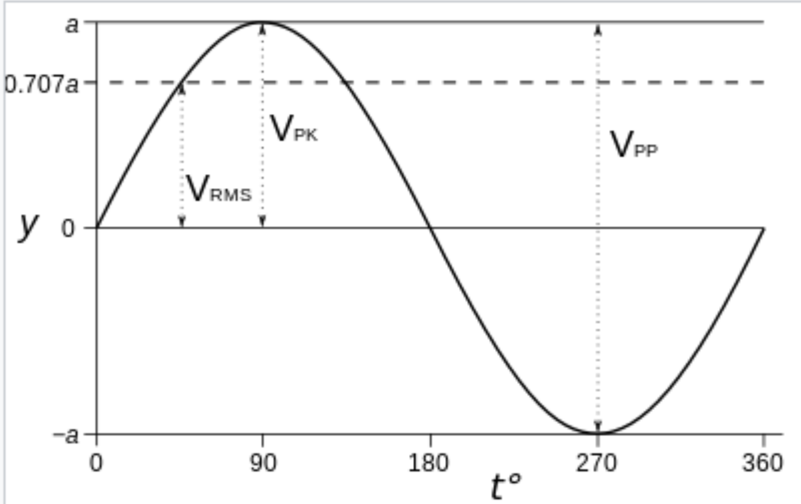
and the RMS for a function over all time is

$$f_{\text{rms}} = \lim_{T\to\infty} \sqrt{\frac{1}{T}\int_{0}^{T} [f(t)]^2 \, dt}.$$

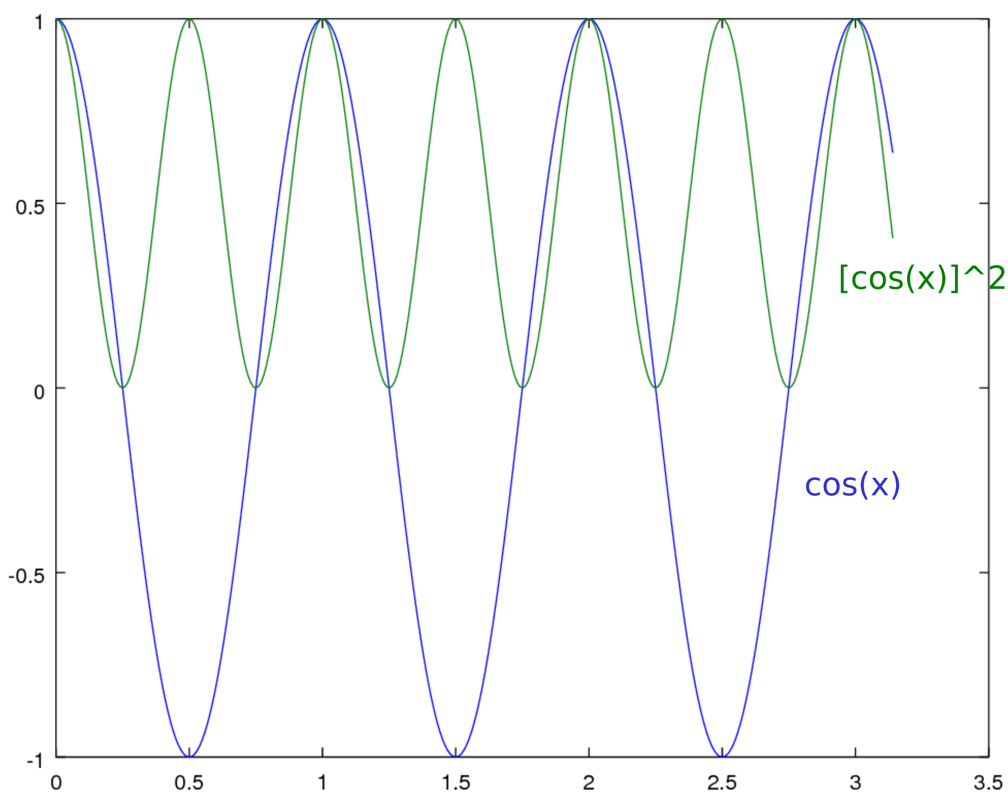
The RMS over all time of a periodic function is equal to the RMS of one period of the function. The RMS value of a continuous function or signal can be approximated by taking the RMS of a sequence of equally spaced samples. Additionally, the RMS value of various waveforms can also be determined without calculus, as shown by Cartwright.[2]

In the case of the RMS statistic of a random process, the expected value is used instead of the mean.

https://en.wikipedia.org/wiki/Root_mean_square



Graph of a sine wave's voltage vs. time (in degrees), showing RMS, peak (PK), and peak-to-peak (PP) voltages.



≥ 0

Square $\cos^2(x)$

mean $\frac{1}{2\pi}\int_0^{2\pi} \cos^2(x)\,dx$

root $\sqrt{\frac{1}{2\pi}\int_0^{2\pi} \cos^2(x)\,dx}$

wxMaxima 15.08.2 [unsaved*]

File Edit Cell Maxima Equations Algebra Calculus Simplify Plot Numeric Help

```
(%i2) (cos(x))^2;
```
(%o2) $\cos(x)^2$

```
(%i3) trigreduce(%);
```
(%o3) $\dfrac{1+\cos(2\,x)}{2}$

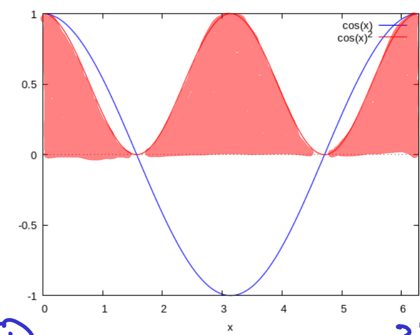
```
-->
(%i4) integrate(%, x);
```
(%o4) $\dfrac{x+\frac{\sin(2\,x)}{2}}{2}$

```
-->
(%i5) integrate((1+cos(2*x))/2 , x, 0, 2*%pi);
```
(%o5) π

```
(%i6) %pi/(2*pi);
```
(%o6) $\dfrac{\pi}{2\,\pi}$

```
(%i7) sqrt(1/2);
```
(%o7) $\dfrac{1}{\sqrt{2}}$

```
(%i8) float(%);
(%o8) 0.7071067811865475
```



area = π

$0.707^2 = 0.5 \Rightarrow \frac{1}{2}$

2π

area = π

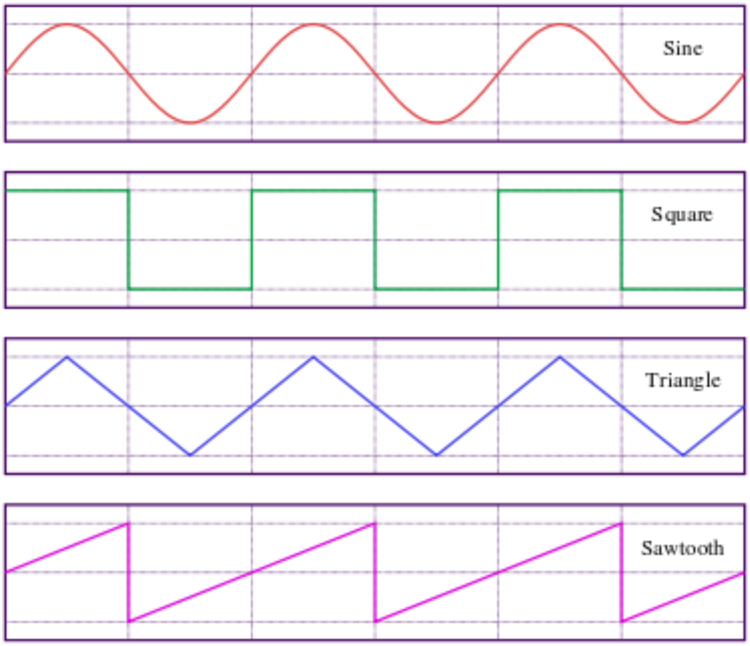
$$\int_0^{2\pi} \cos^2(x)\,dx = \int_0^{2\pi} \frac{1}{2}\left(1+\cos(2x)\right)dx = \pi$$

$$\frac{1}{2\pi}\int_0^{2\pi} \cos^2(x) = \frac{1}{2}$$

$$\sqrt{\frac{1}{2\pi}\int_0^{2\pi} \cos^2(x)} = \sqrt{\frac{1}{2}} = 0.707$$

Welcome to wxMaxima

Ready for user input

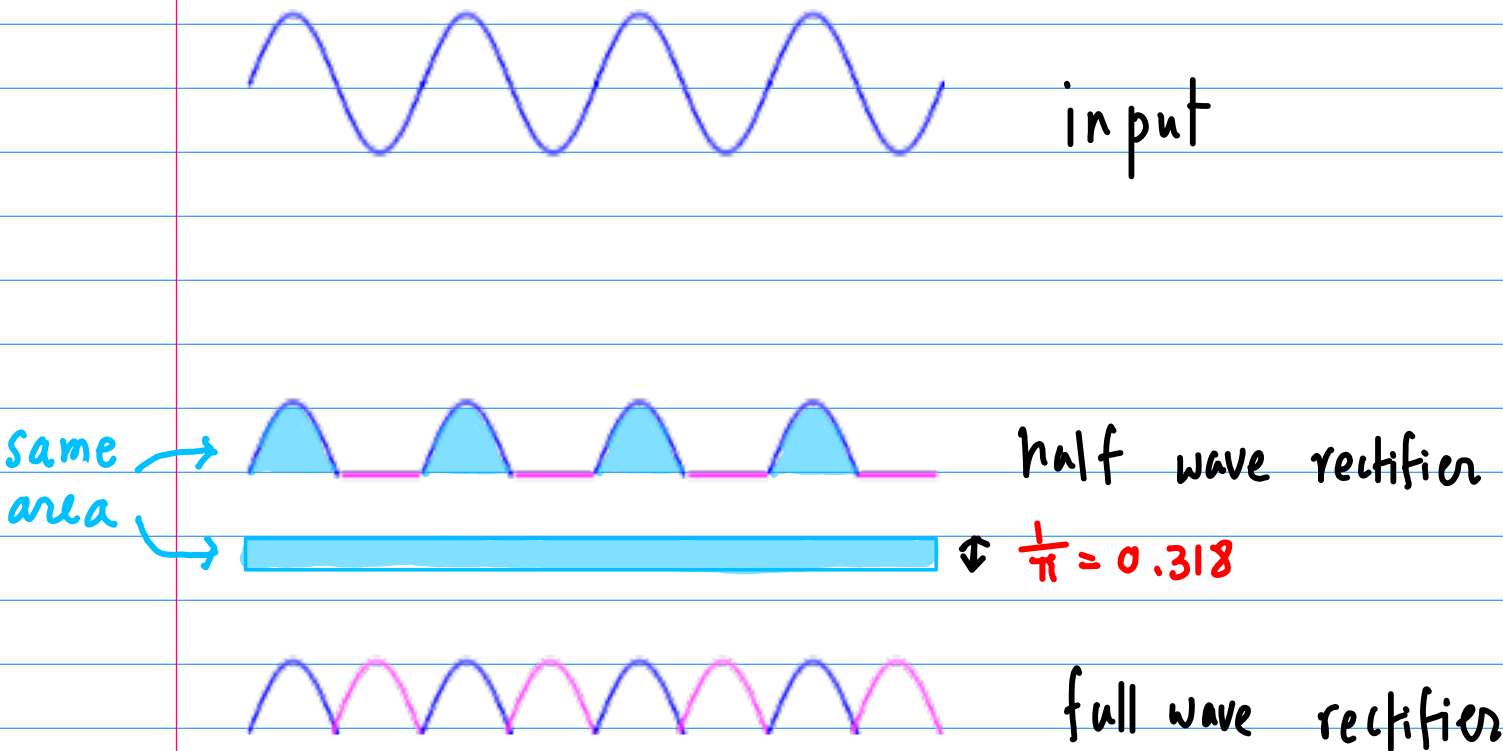


A_0

Sine, square, triangle, and sawtooth waveforms.

Waveform	Equation	RMS
DC, constant	$y = A_0$	A_0
Sine wave	$y = A_1 \sin(2\pi f t)$	$\frac{A_1}{\sqrt{2}}$
Square wave	$y = \begin{cases} A_1 & \operatorname{frac}(ft) < 0.5 \\ -A_1 & \operatorname{frac}(ft) > 0.5 \end{cases}$	A_1
DC-shifted square wave	$y = A_0 + \begin{cases} A_1 & \operatorname{frac}(ft) < 0.5 \\ -A_1 & \operatorname{frac}(ft) > 0.5 \end{cases}$	$\sqrt{A_0^2 + A_1^2}$
Modified sine wave	$y = \begin{cases} 0 & \operatorname{frac}(ft) < 0.25 \\ A_1 & 0.25 < \operatorname{frac}(ft) < 0.5 \\ 0 & 0.5 < \operatorname{frac}(ft) < 0.75 \\ -A_1 & \operatorname{frac}(ft) > 0.75 \end{cases}$	$\frac{A_1}{\sqrt{2}}$
Triangle wave	$y = \lvert 2A_1 \operatorname{frac}(ft) - A_1 \rvert$	$\frac{A_1}{\sqrt{3}}$
Sawtooth wave	$y = 2A_1 \operatorname{frac}(ft) - A_1$	$\frac{A_1}{\sqrt{3}}$
Pulse train	$y = \begin{cases} A_1 & \operatorname{frac}(ft) < D \\ 0 & \operatorname{frac}(ft) > D \end{cases}$	$A_1\sqrt{D}$
Phase-to-phase voltage	$y = A_1 \sin(t) - A_1 \sin\left(t - \frac{2\pi}{3}\right)$	$A_1\sqrt{\frac{3}{2}}$

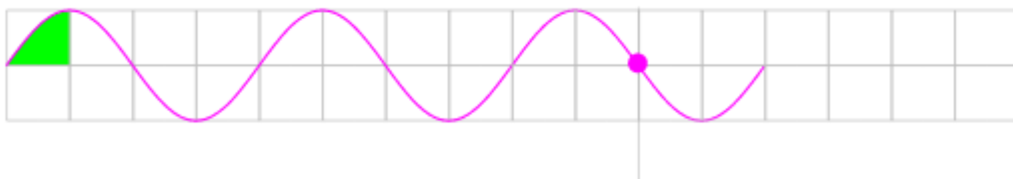
DC value of Half-Wave Signal



C2

$f(x) = \sin(x)$

$\int_0^{\pi/2} \sin(t)\, dt = 1$



D1

$f(x) = \cos(x)$

$\int_0^{\pi/2} \cos(x)\, dx = 1$

0 1 0 -1 0 1 0 -1 0 1 0 -1 **area - 0**

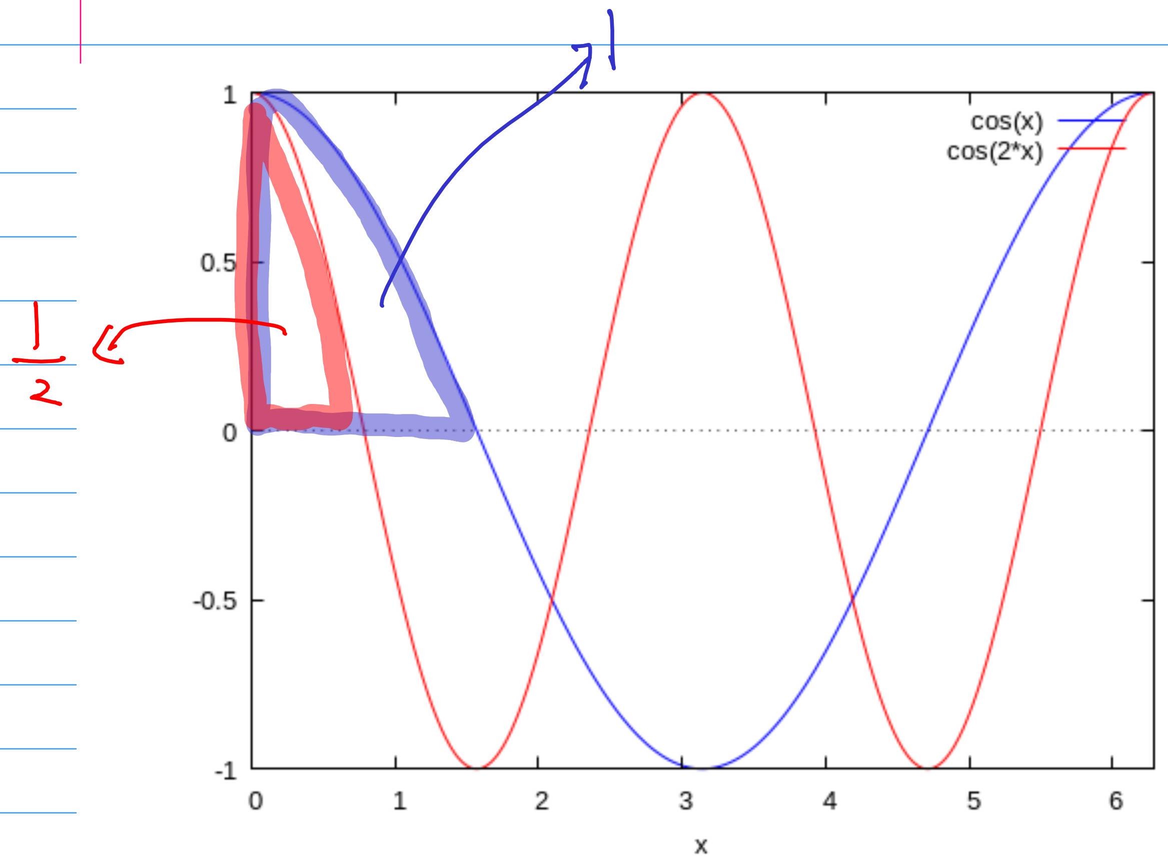
$= \sin(x) - 0$

```
(%i15) integrate(cos(x), x, 0, %pi/2);
(%o15) 1
```

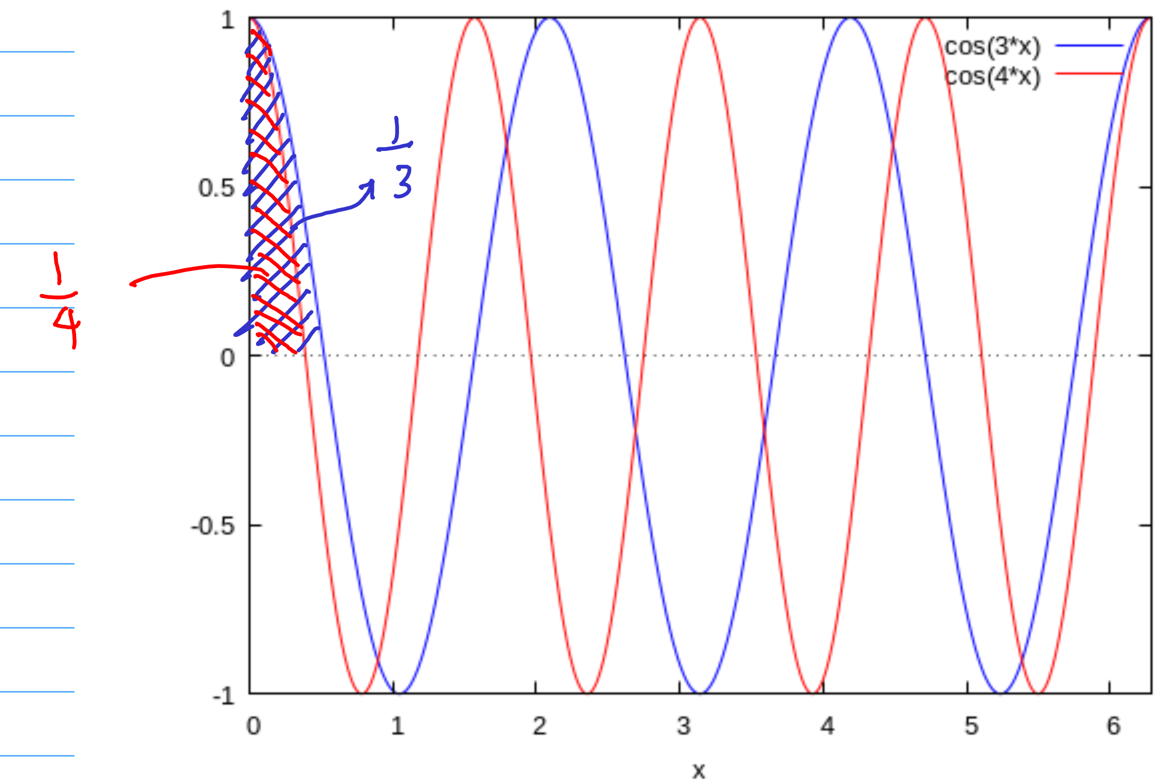
```
(%i3) integrate(cos(2*x), x, 0, %pi/4);
```
(%o3) $\frac{1}{2}$

```
(%i6) integrate(cos(3*x), x, 0, %pi/6);
```
(%o6) $\frac{1}{3}$

```
(%i7) integrate(cos(4*x), x, 0, %pi/8);
```
(%o7) $\frac{1}{4}$



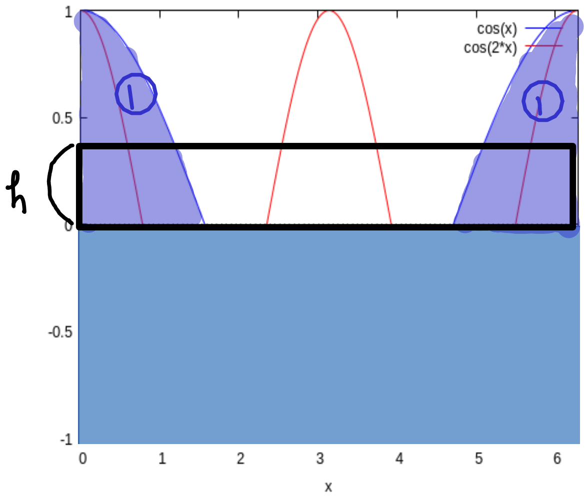
cos(x)
cos(2*x)
1
1/2
x



cos(3*x)
cos(4*x)
1/3
1/4
x

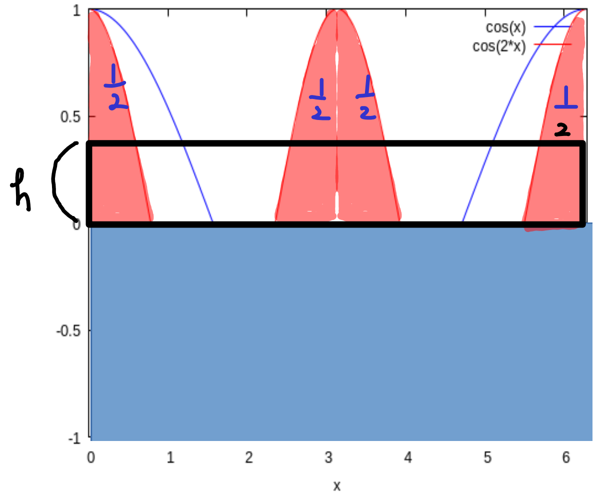
cos(x)

$1+1 = 2\pi h \qquad h = \frac{1}{\pi}$



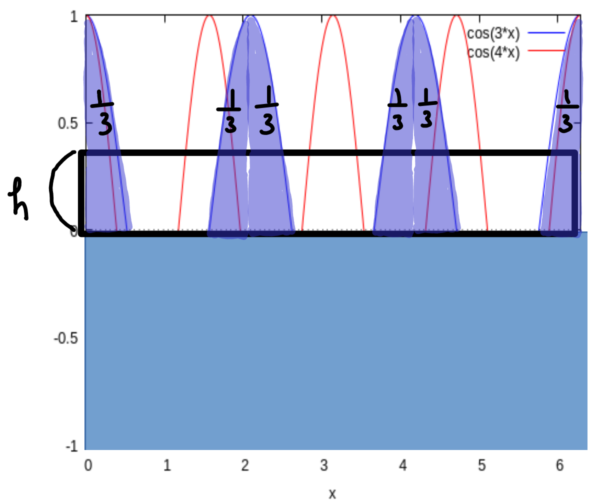
cos(2x)

$\frac{1}{2}+\frac{1}{2}+\frac{1}{2}+\frac{1}{2} = 2\pi h \qquad h = \frac{1}{\pi}$



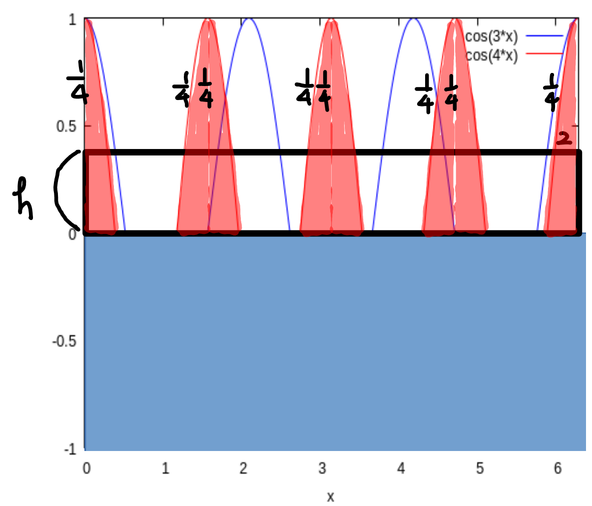
cos(3x)

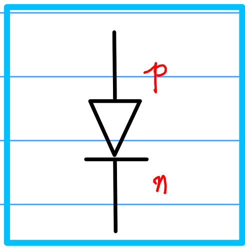
$\frac{1}{3}+\frac{1}{3}+\frac{1}{3}+\frac{1}{3}+\frac{1}{3}+\frac{1}{3} = 2\pi h \qquad h = \pi$

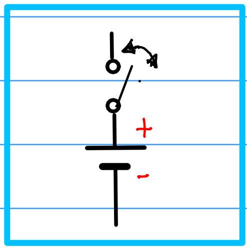


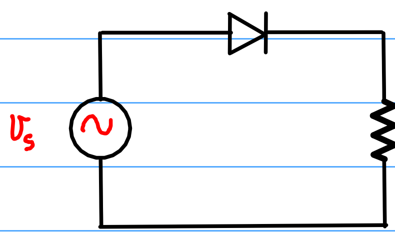
cos(4x)

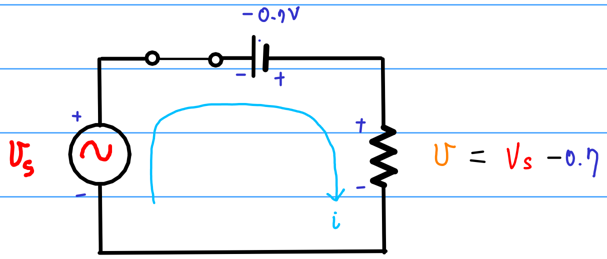
$\frac{1}{4}+\frac{1}{4}+\frac{1}{4}+\frac{1}{4}+\frac{1}{4}+\frac{1}{4}+\frac{1}{4}+\frac{1}{4} = 2\pi h \qquad h = \frac{1}{\pi}$

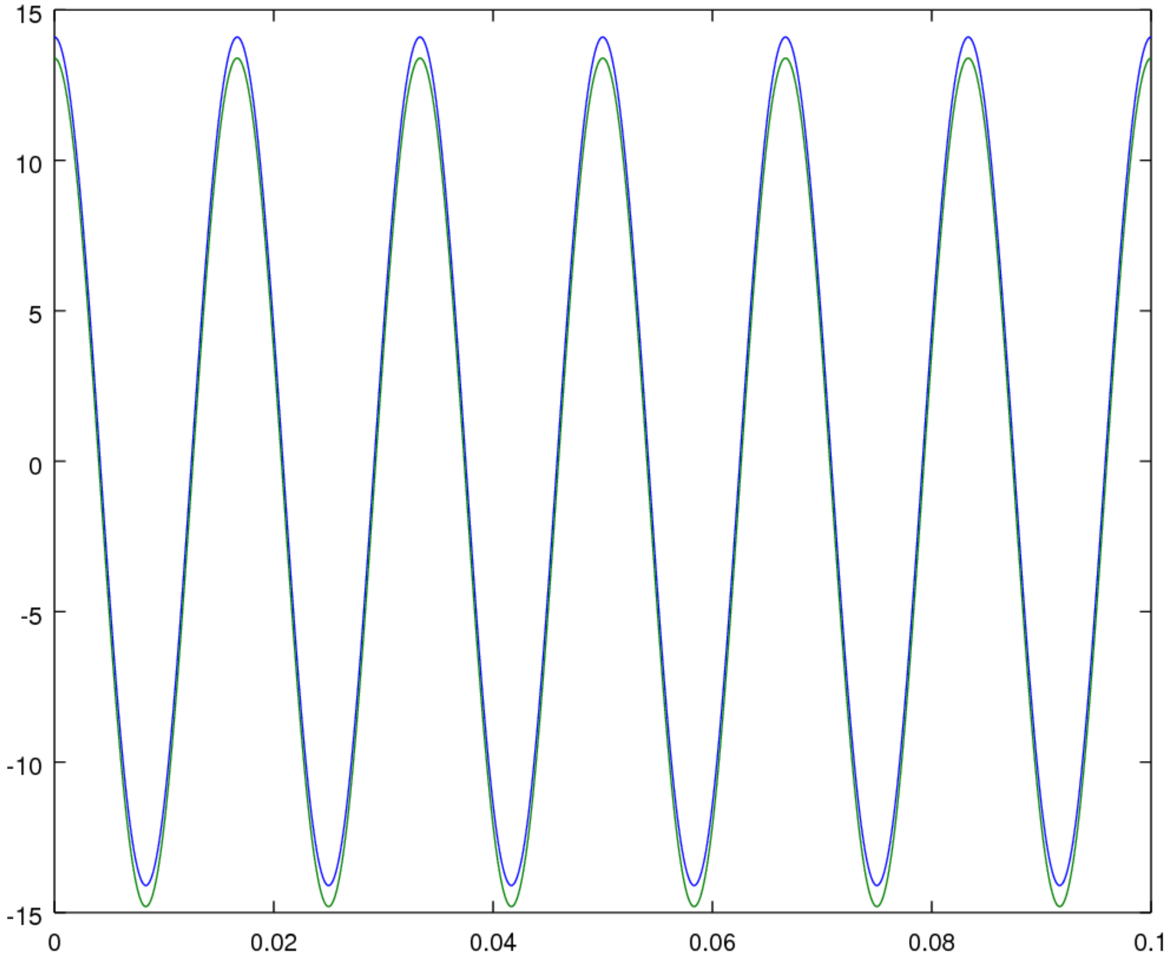



p
n


+
-

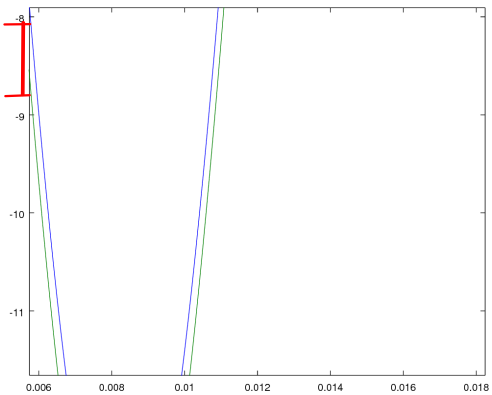

v_s


-0.7V
- +
+
-
v_s
+
-
i
$v = V_s - 0.7$



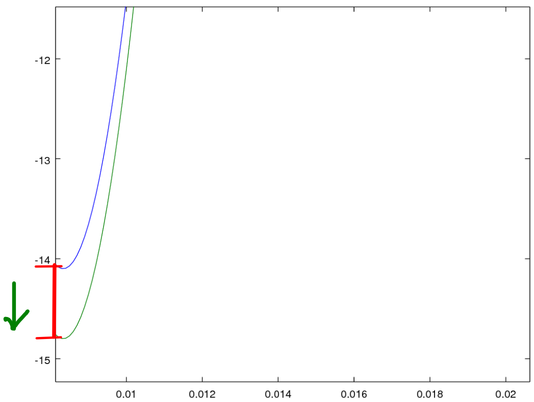

```
t = 0:0.0001:0.1;
y = 14.1*cos(2*pi*60*t);
plot(t, y)
z = y -0.7
plot(t, y, t, z);
```

0.7V ↓



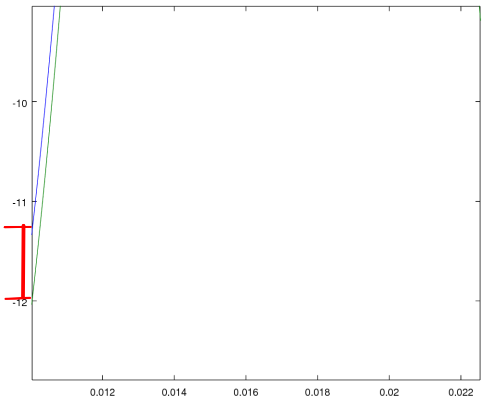
-8
-9
-10
-11
0.006
0.008
0.01
0.012
0.014
0.016
0.018

0.7V ↓



-12
-13
-14
-15
0.01
0.012
0.014
0.016
0.018
0.02

0.7V ↓

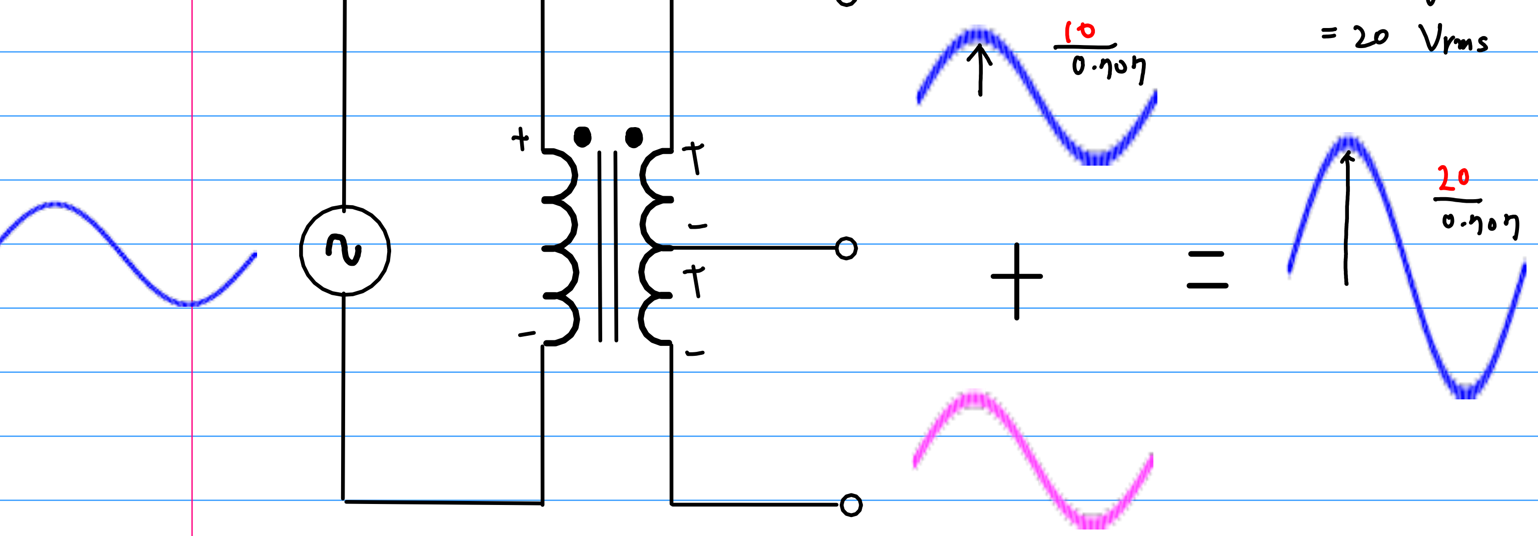


-10
-11
-12
0.012
0.014
0.016
0.018
0.02
0.022

#8

input voltage of the half-wave rectifier $= 10\ V_{rms}$

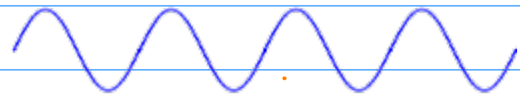
secondary voltage $= 20\ V_{rms}$



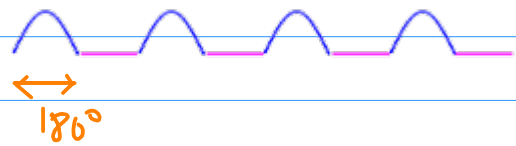
$$v_p = \frac{10}{0.707} = 14.1\ V$$

peak load voltage

10

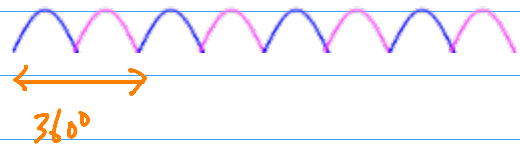


input



half wave rectifier

current flows only for 180°

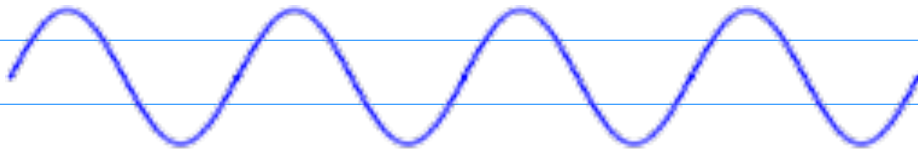


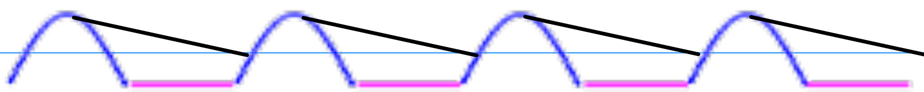
full wave rectifier

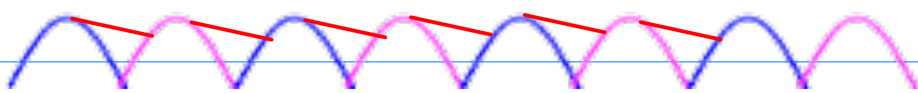
current flows for 360°

#14

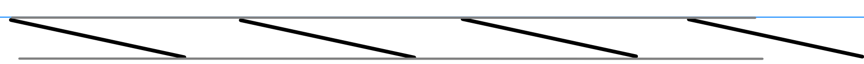
the same secondary voltage
and filter (R, C)







Full-wave  small ripple

Half-wave  large ripple

#15

Full-wave rectifier

center tap