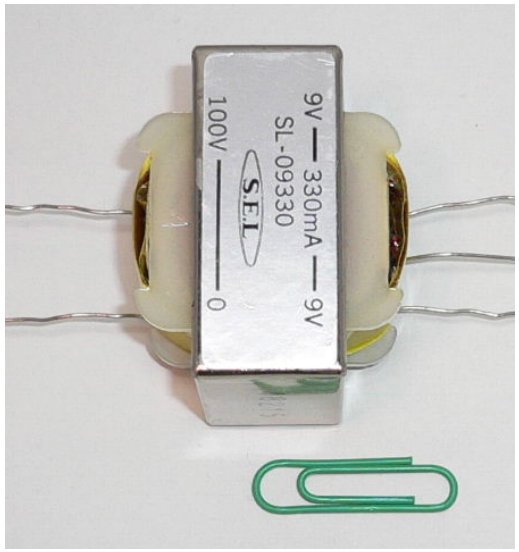
Power Electronics
No. 2: Rectifier

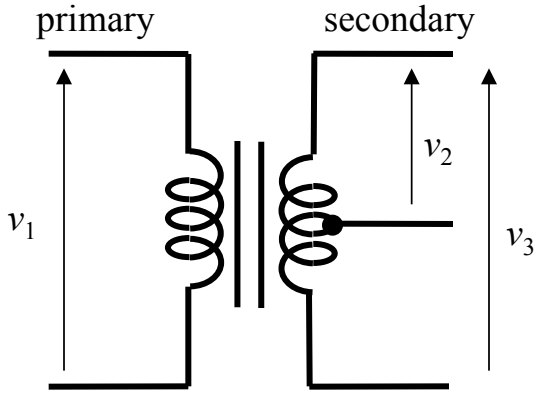
Takeshi Furuhashi

furuhashi_at_cse.nagoya-u.ac.jp

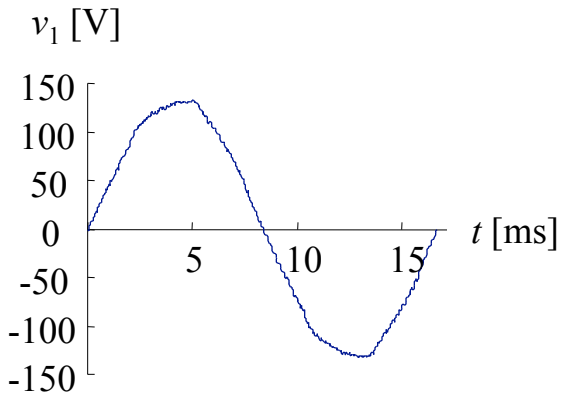


Example of a transformer

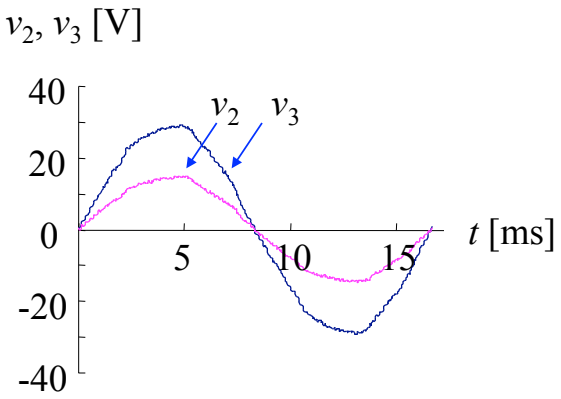
primary:100V secondary: 9V-0-9V



(a) Transformer symbol

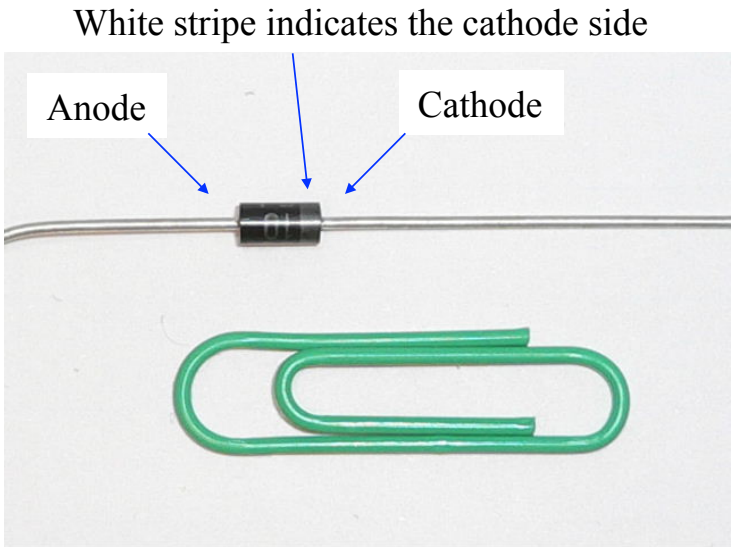


(b) Voltage waveform on the primary side

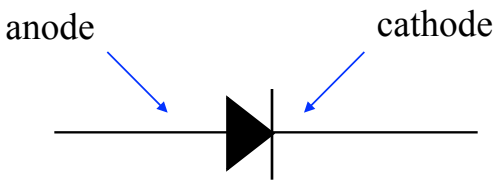


(c) Voltage waveform on the secondary side

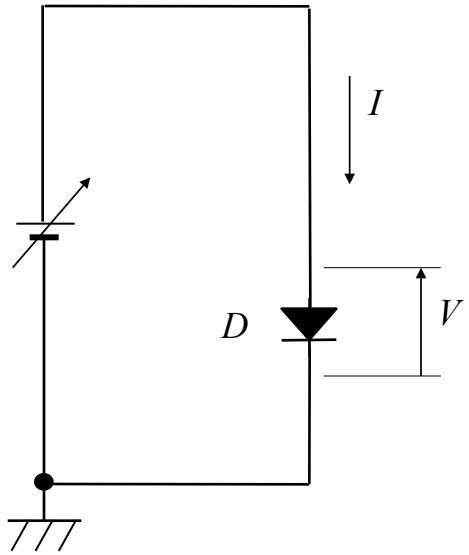
Input/output voltage waveforms of the transformer



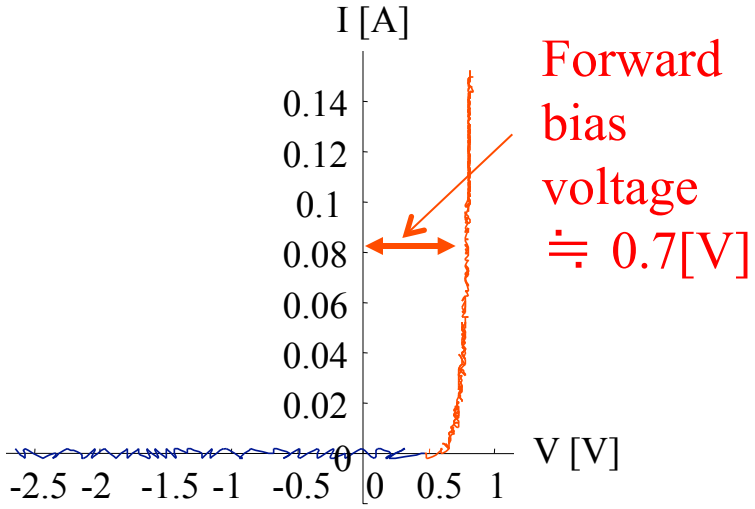
Example of a diode(100V, 1A)



Diode symbol

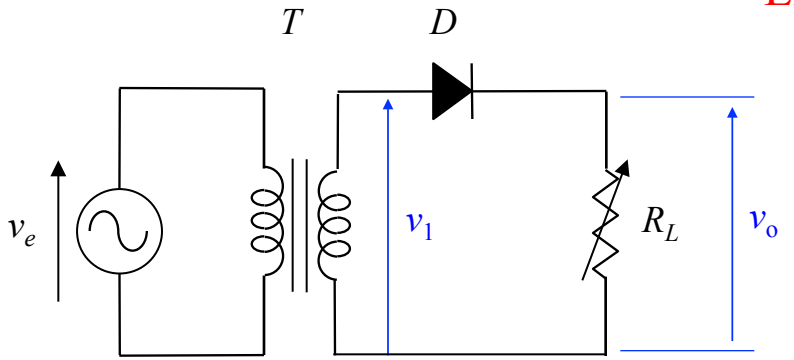


(a) Measurement of diode characteristics



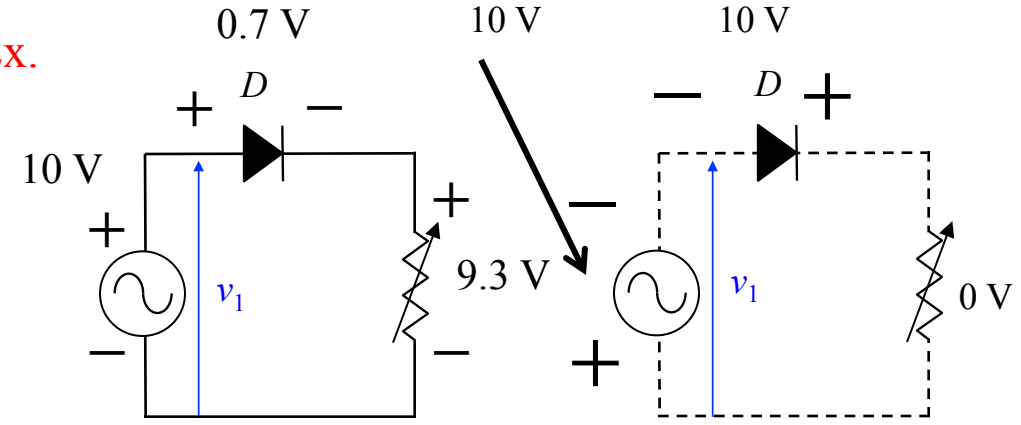
(b) Voltage vs. current characteristics

Example diode characteristics



Half-wave rectifier

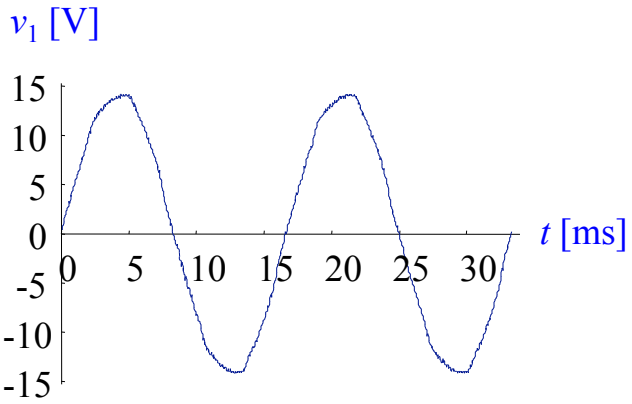
Ex.



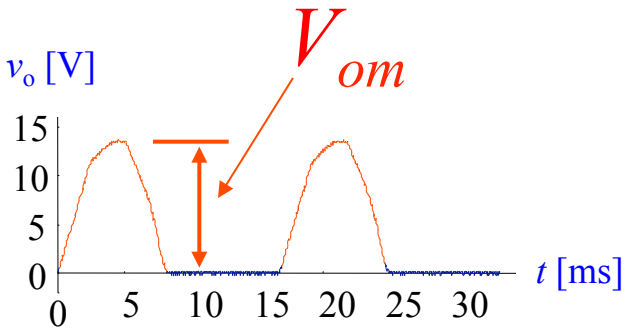
(a) Diode is conducting.

(b) Diode is not conducting.

Operating modes of the half-wave rectifier

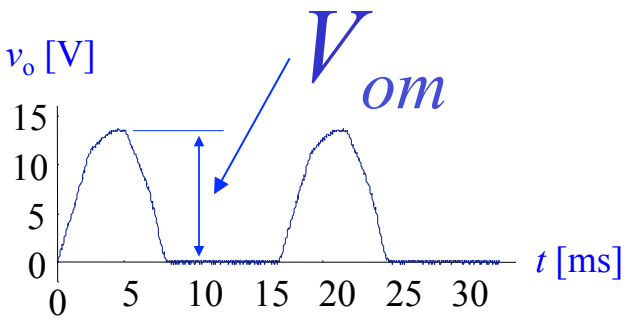


(a) Waveform of voltage v_1



(b) Waveform of output voltage v_o

Waveforms of the half-bridge rectifier



(b) Waveform of output voltage v_o

$$\overline{v_o} = \frac{1}{2\pi}\int_0^{2\pi} v_o \, d\theta$$

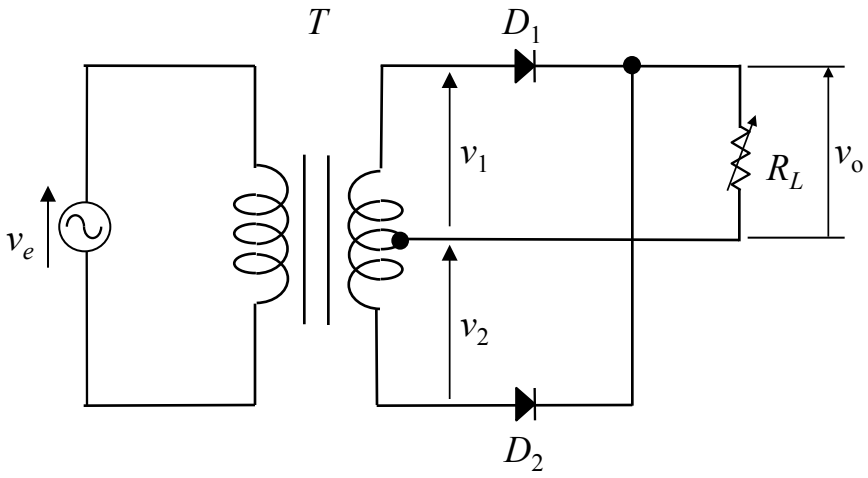
$$= \frac{1}{2\pi}\int_0^{\pi} V_{om} \sin\theta \, d\theta$$

$$= \frac{V_{om}}{2\pi}\int_0^{\pi} \sin\theta \, d\theta$$

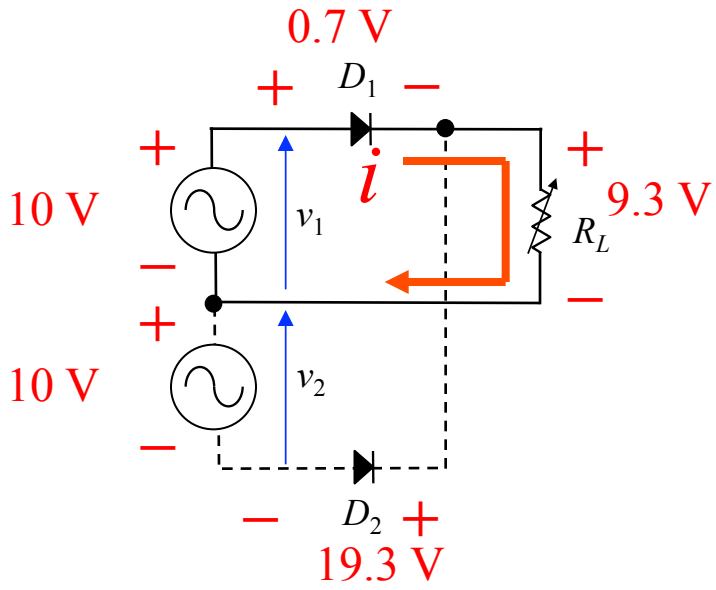
$$= \frac{V_{om}}{2\pi}\left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{V_{om}}{2\pi}\left(1+1\right)$$

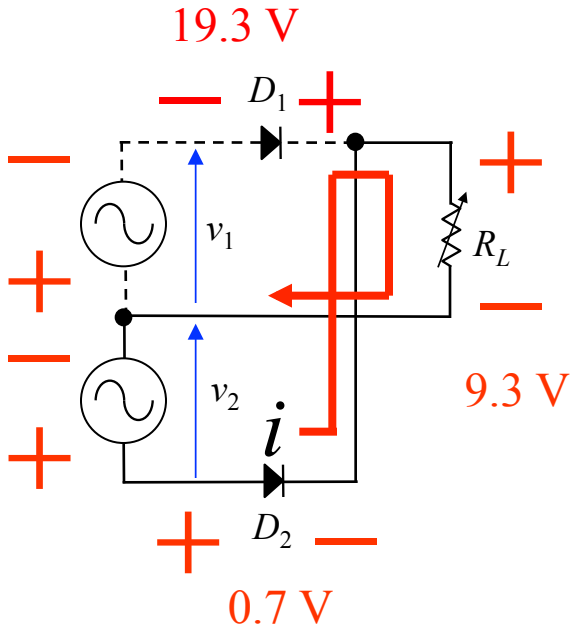
$$= \frac{V_{om}}{\pi}$$



Full-wave rectifier

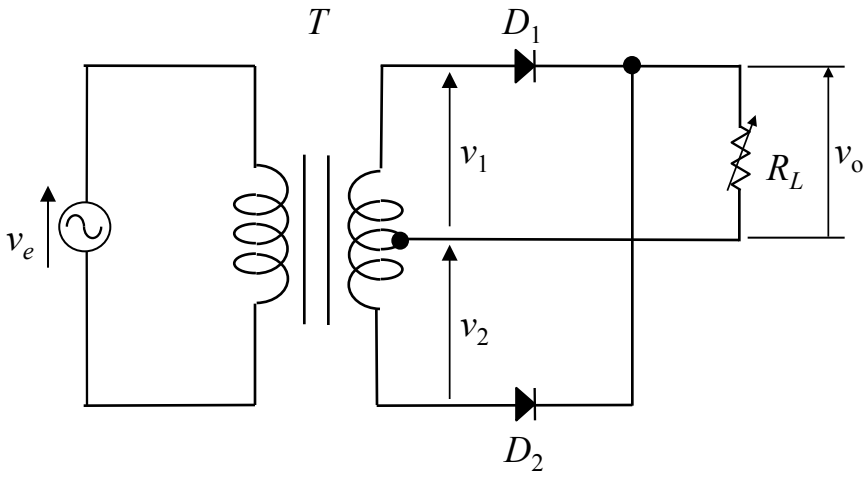


(a) Diode D_1 is conducting

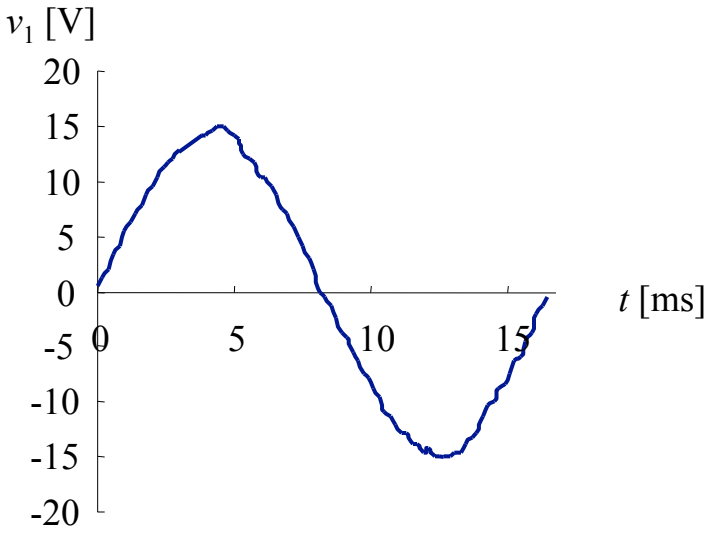


(b) Diode D_2 is conducting.

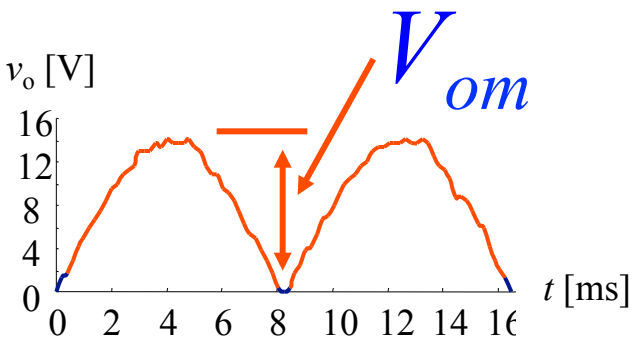
Operating modes of full-wave rectifier



Full-wave rectifier

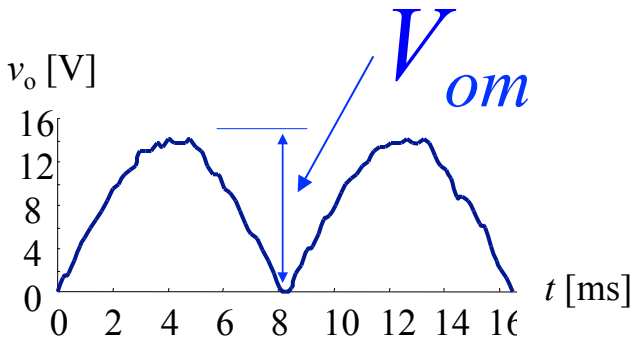


(a) Waveform of voltage v_1



(b) Waveform of valtage v_o

Waveforms of voltages of the full-wave rectifier



(b) Waveform of voltage v_o

$$\bar{v}_o = \frac{1}{2\pi}\int_0^{2\pi} v_o \, d\theta$$

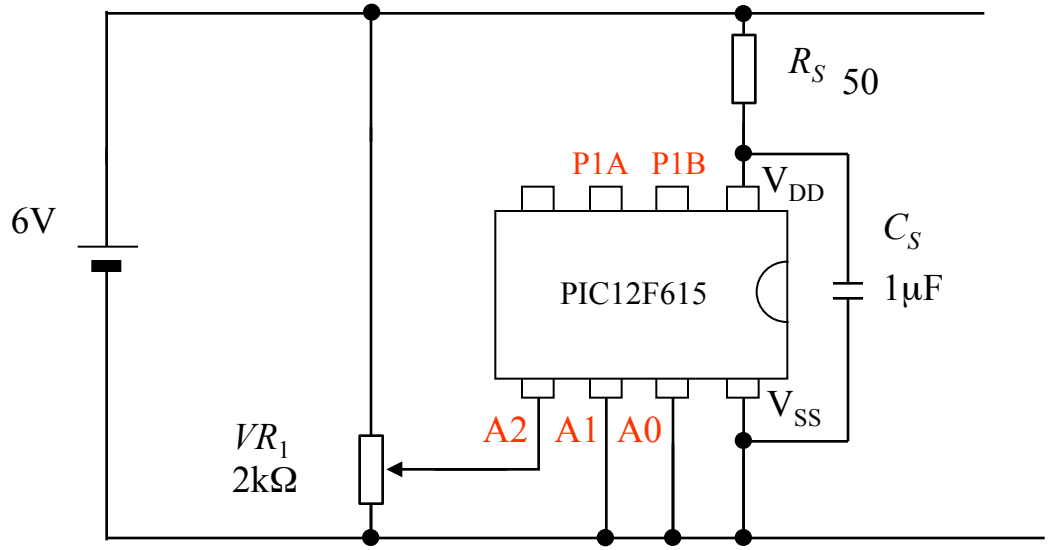
$$= \frac{1}{2\pi}\left(\int_0^{\pi} V_{om}\sin\theta \, d\theta + \int_{\pi}^{2\pi} (-V_{om}\sin\theta)\, d\theta\right)$$

$$= \frac{V_{om}}{2\pi}\left\{\left[-\cos\theta\right]_0^{\pi} - \left[-\cos\theta\right]_{\pi}^{2\pi}\right\}$$

$$= \frac{V_{om}}{2\pi}(1+1+1+1)$$

$$= \frac{2V_{om}}{\pi}$$

Sine wave generator and PWM waveform generator using a PIC micro computer (PIC12F615)



A1 A0 = 00: Mode for sine wave generation

P1A, P1B = output pins for a sine wave with 0.25-2Hz

A2 = input pin for frequency command

A1 A0 = 01: Mode for very slow PWM

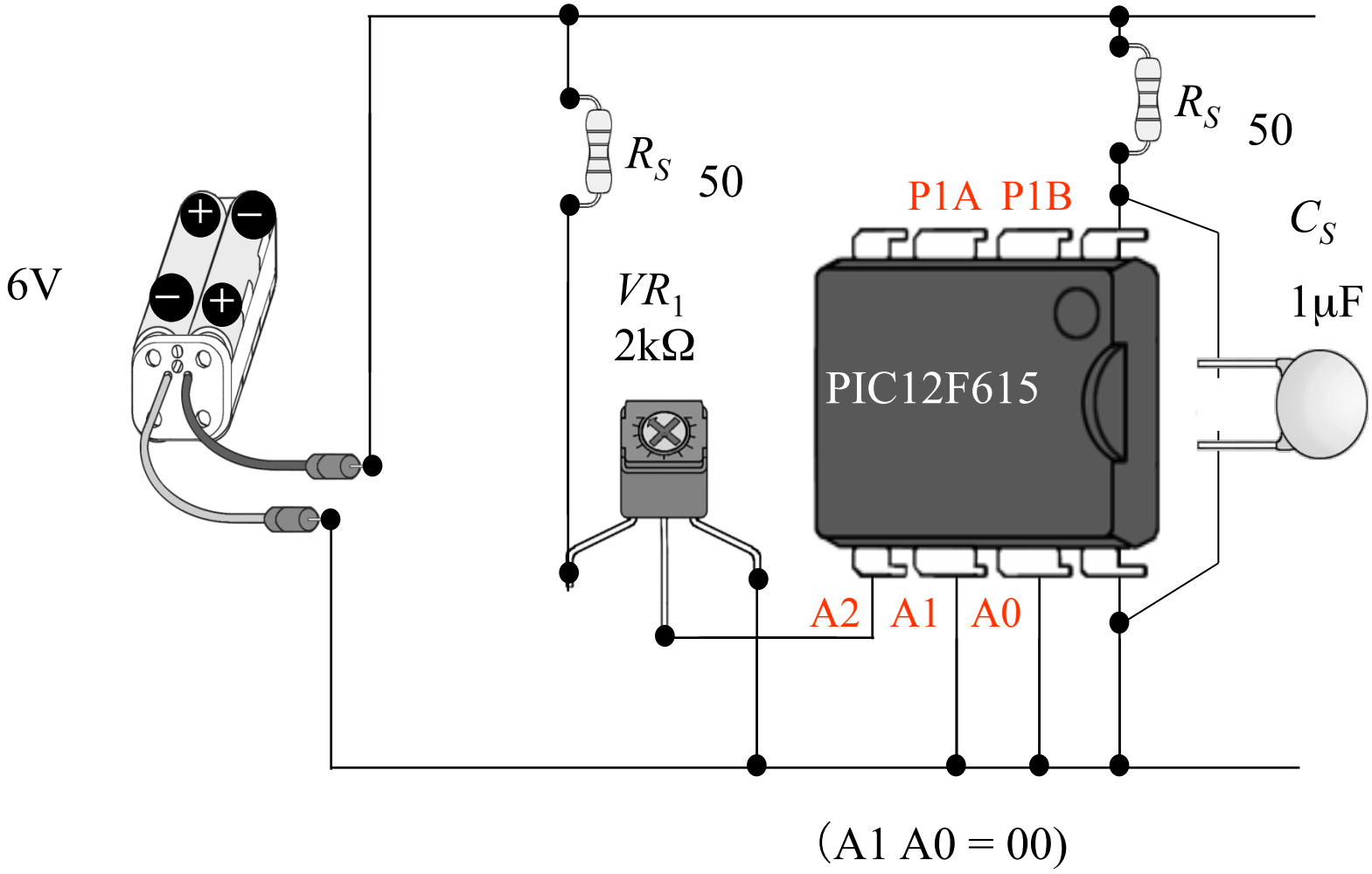
P1A = output pins for 0.5Hz PWM, A2 = input pin for voltage command

A1 A0 = 10: Mode for motor drive

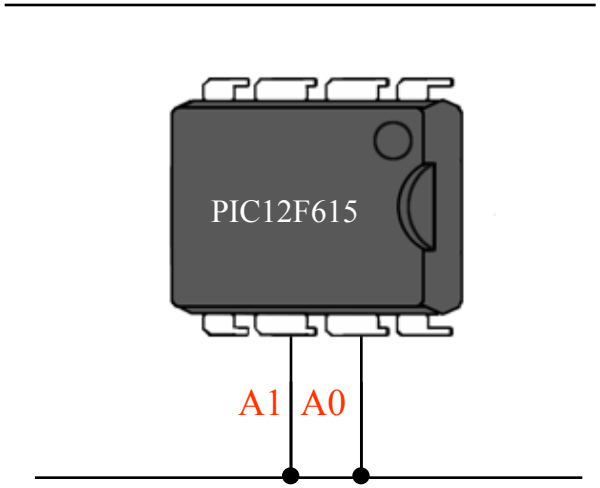
P1A, P1B = output pins for 12.5kHz PWM, A2 = input pin for voltage command

A0 = 11: Mode for D-class amplifier

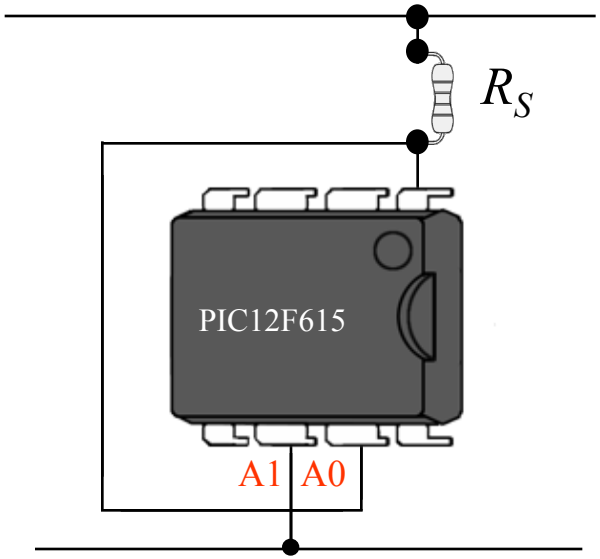
P1A = output pins for 15kHz PWM, A2 = input pin for sound signal



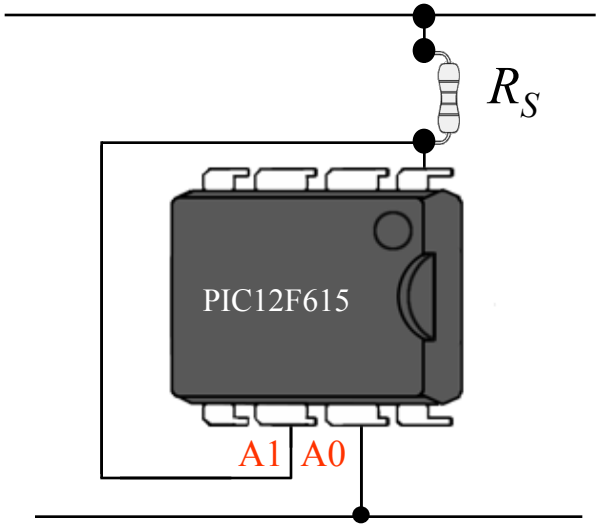
Wiring diagram



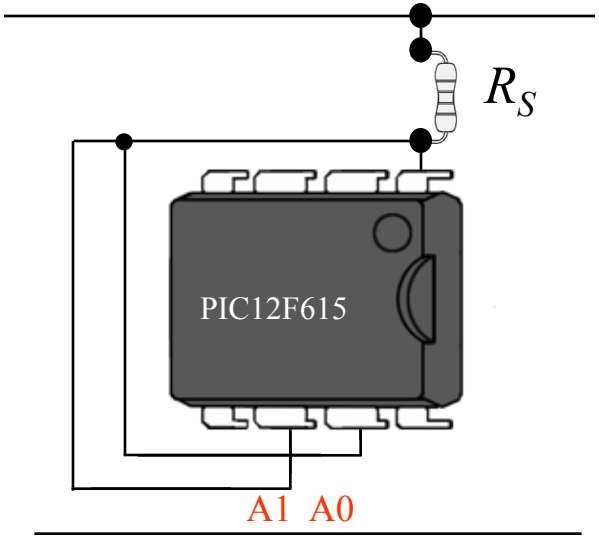
A1 A0 = 00: Mode for sine wave generation



A1 A0 = 01: Mode for very slow PWM



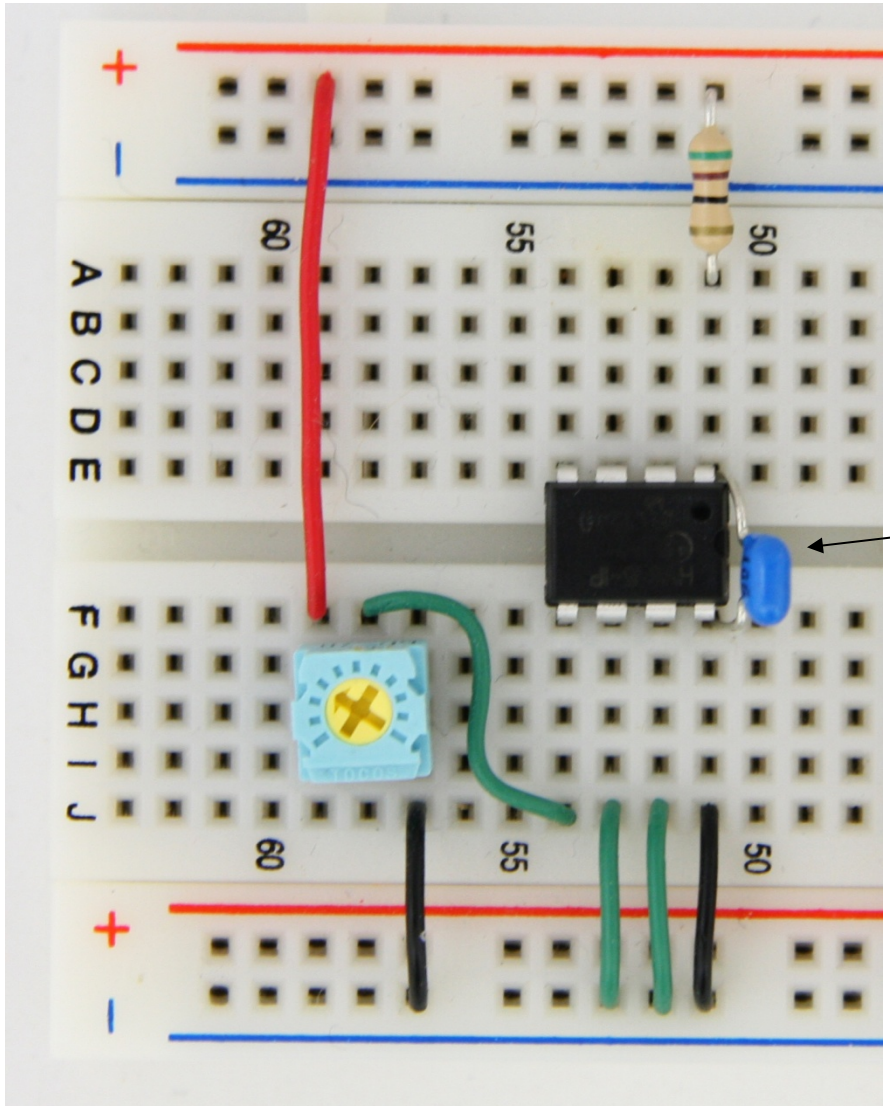
A1 A0 = 10: Mode for motor drive



A1 A0 = 11: Mode for D-class amplifier

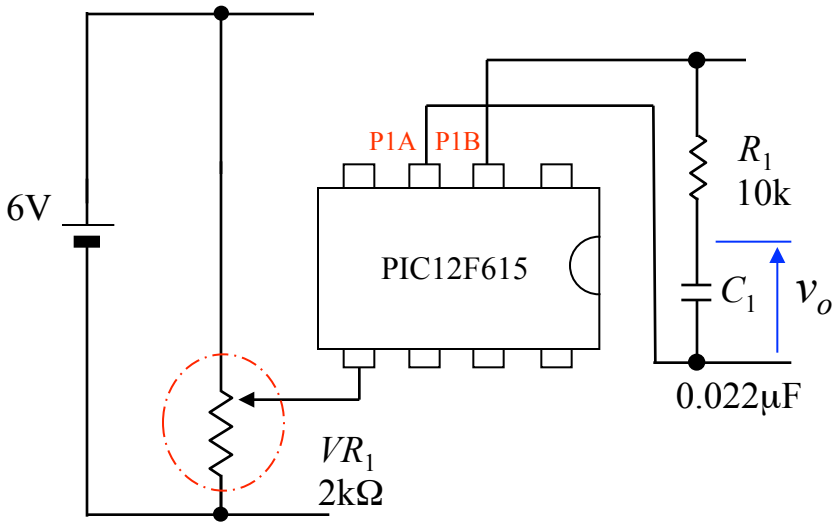
Photo of constructed circuit

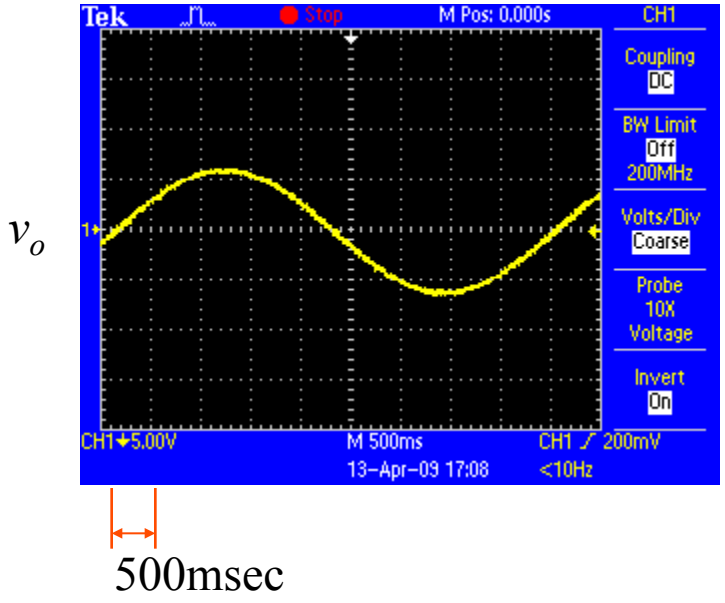
（This circuit will be used for most of circuit construction practices.）

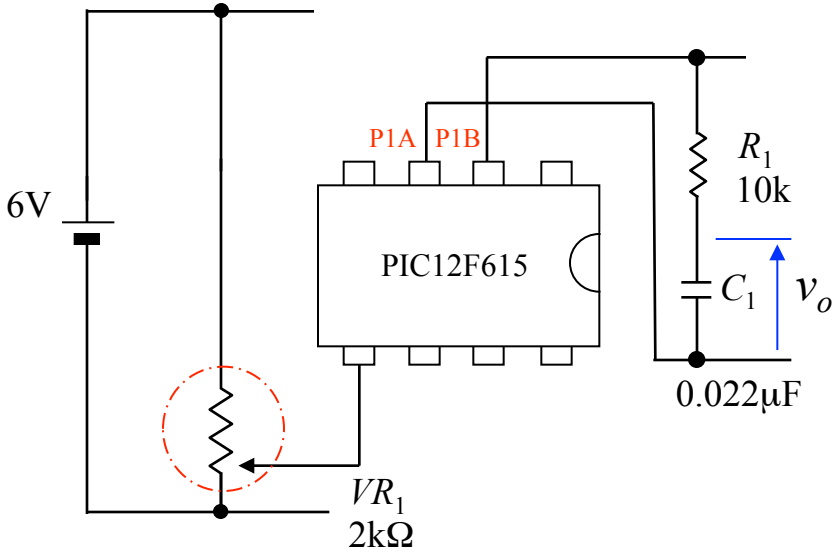


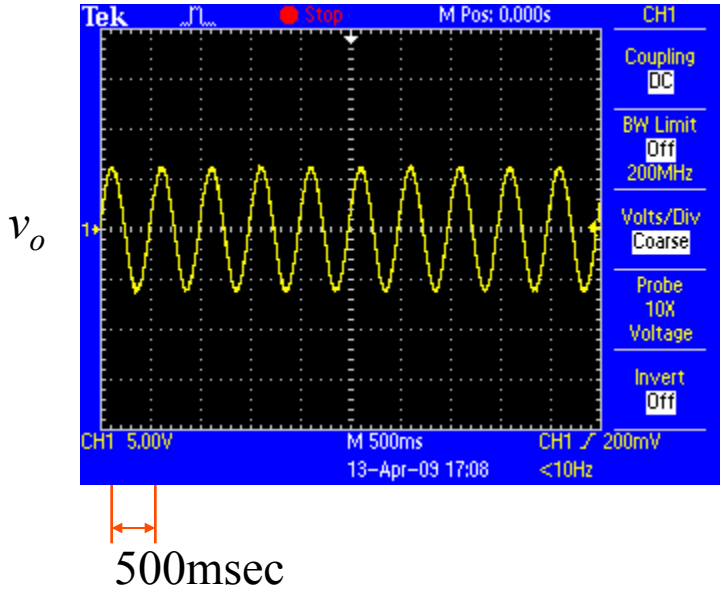
It is better to insert the capacitor wires into the same holes in which the microcontroller pins are inserted.

Sine wave generation

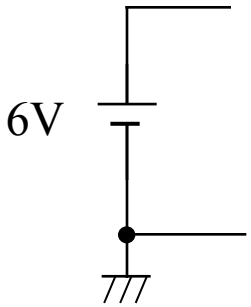


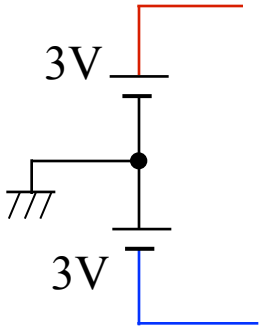


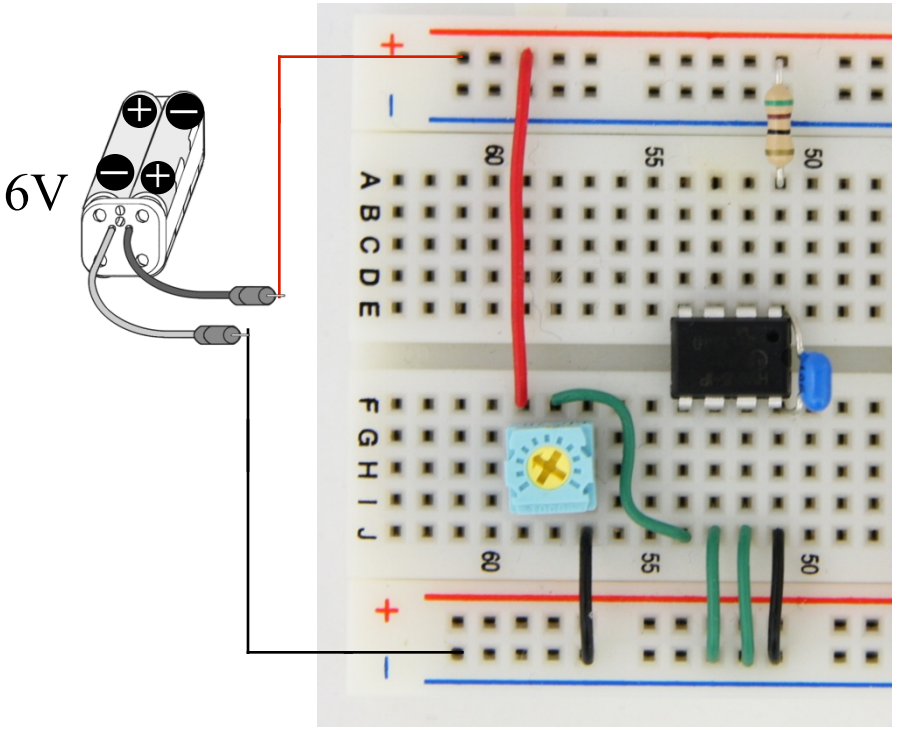




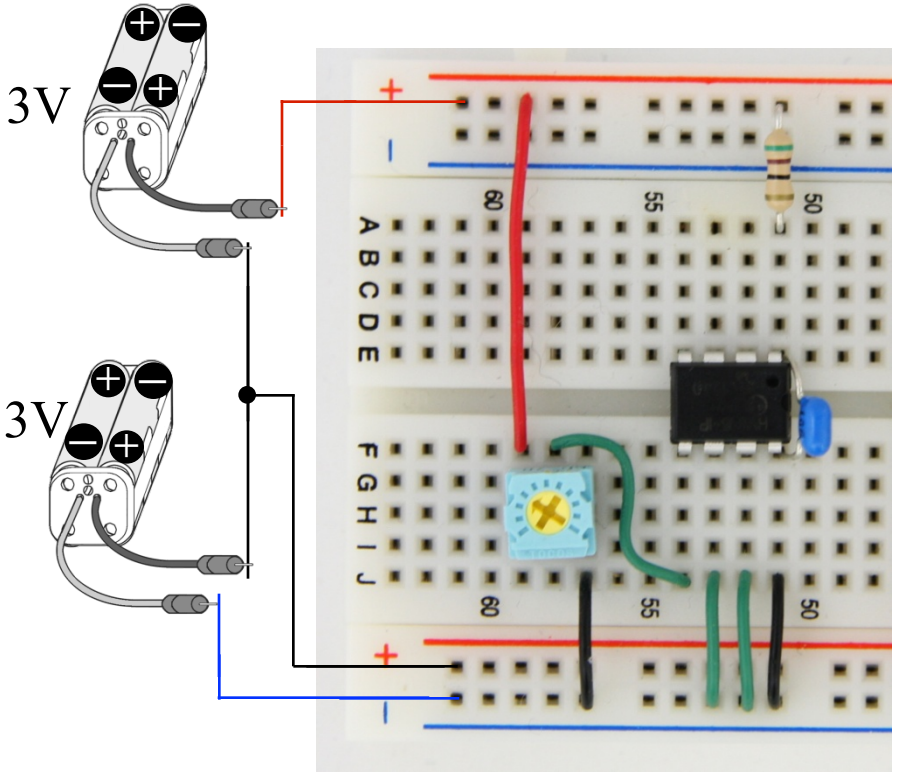
Battery connections





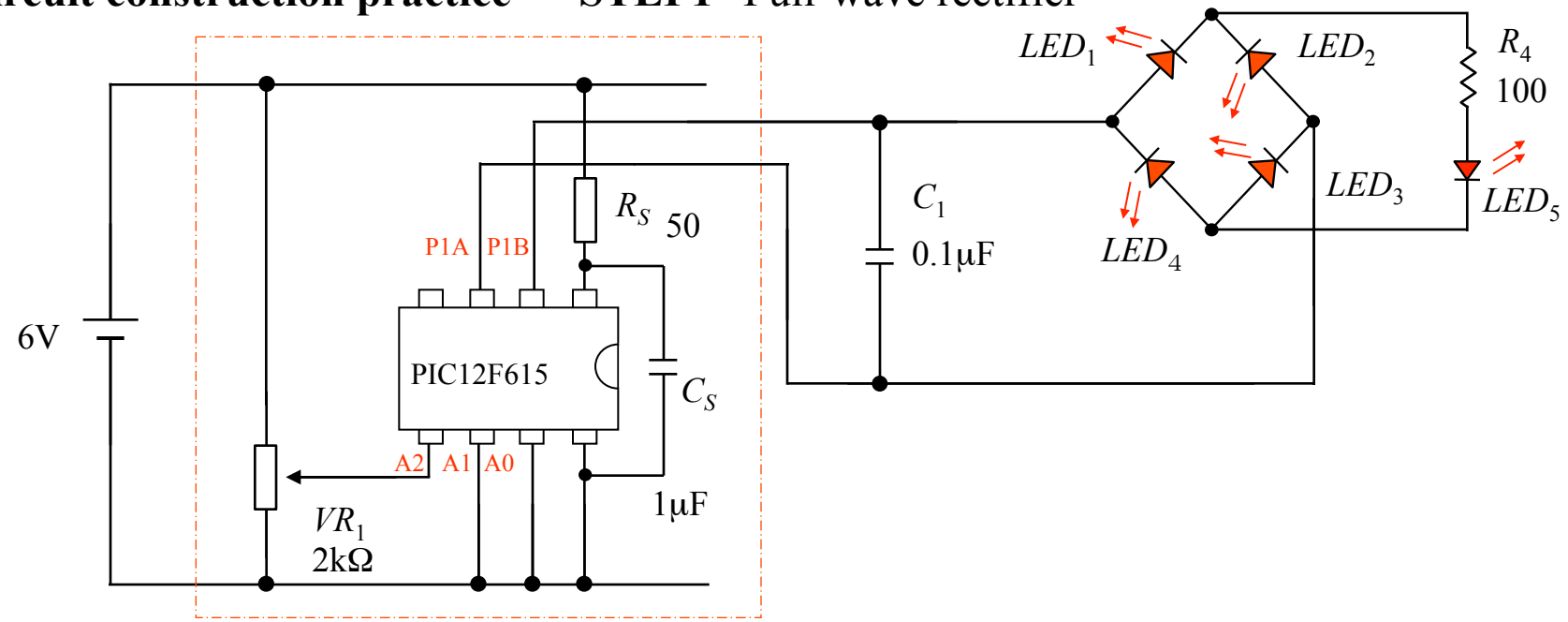


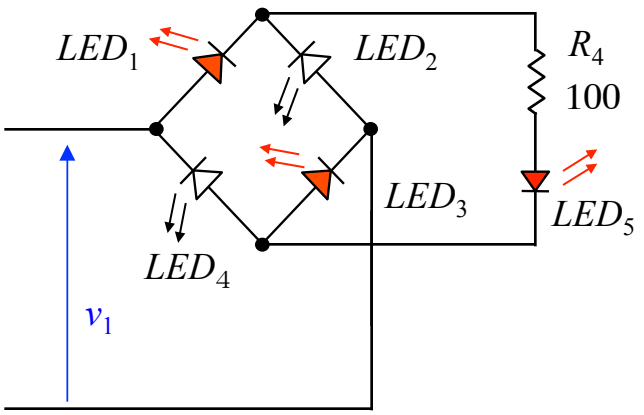
6 V-type battery



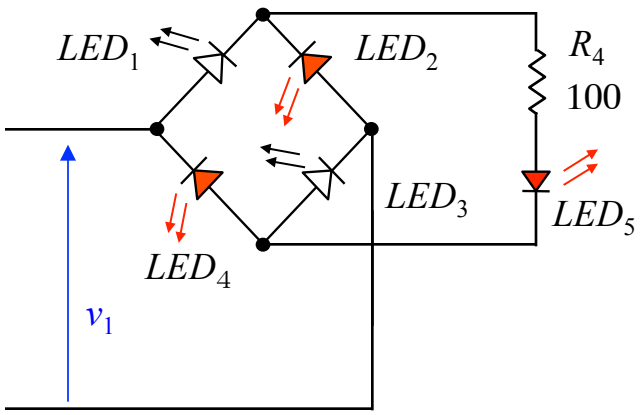
Two 3 V-type batteries

Circuit construction practice **STEP1** Full-wave rectifier

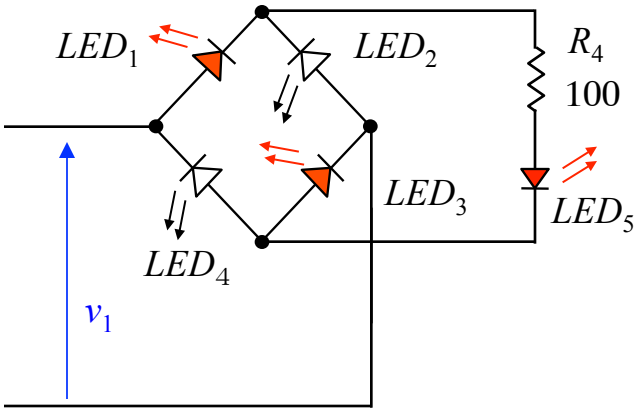




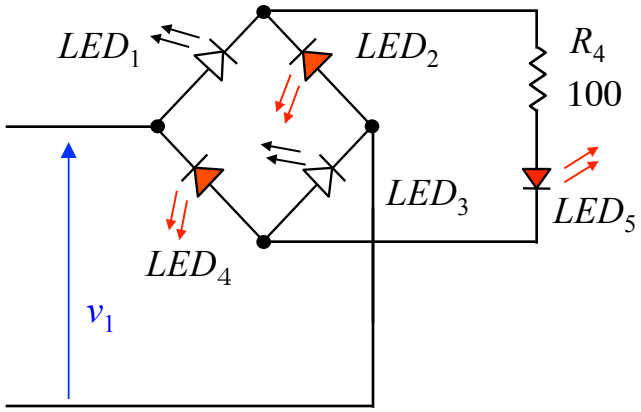
When $v_1 > 0$, LED1, 3, 5 conducts.



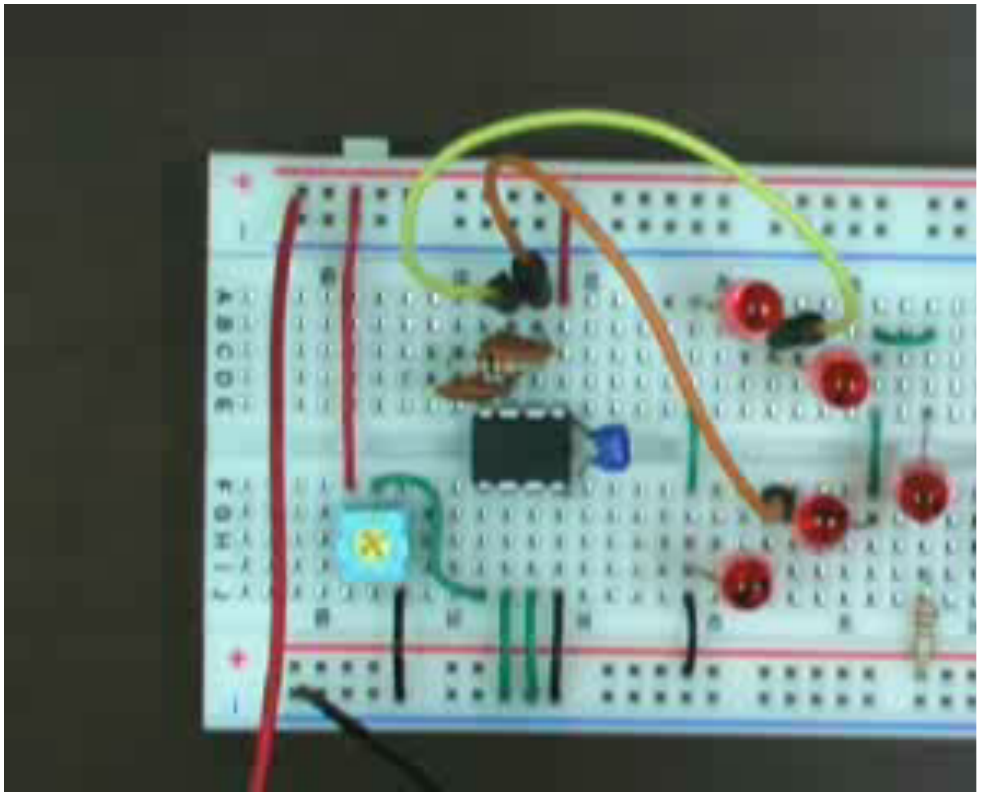
When $v_1 < 0$, LED2, 4, 5 conducts



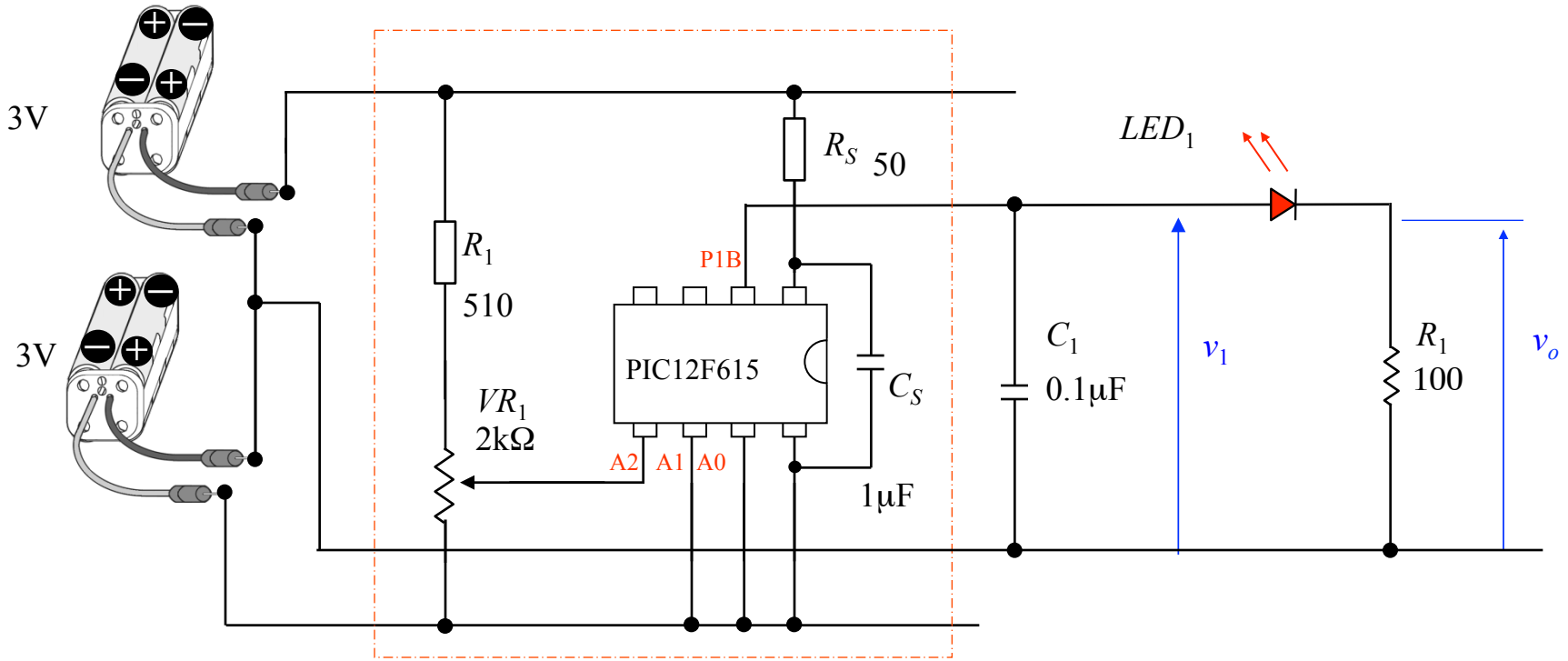
When $v_1 > 0$, LED1, 3, 5 conducts.



When $v_1 < 0$, LED2, 4, 5 conducts

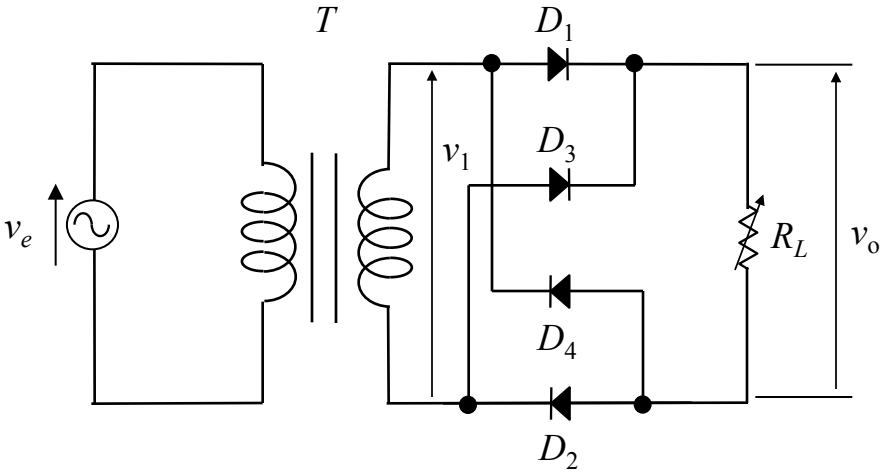


For your further study: Half-wave rectifier

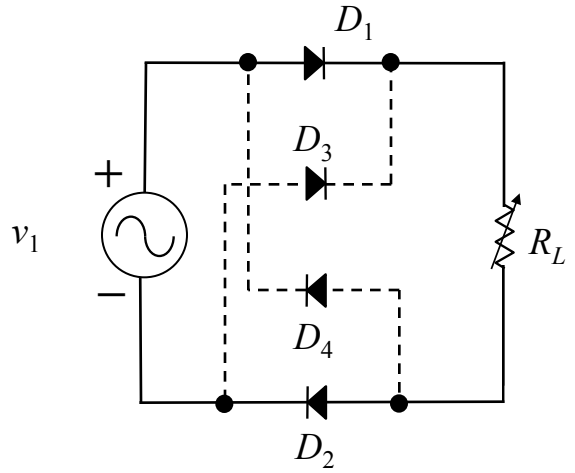


STEP 1. Problem 1

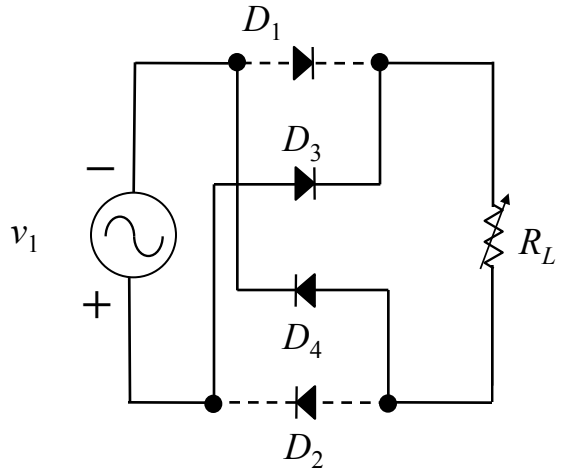
What are the voltage values across diodes D_1, D_2, D_3, and D_4? Which polarities do they have? Indicate the values and polarities in figure (a) for the case where $v_1 = +10$ V, and in (b) for the case where $v_1 = -10$[V]. The forward bias voltage of the diodes is 0.7 V. Indicate the routes of the current.



Bridge rectifier



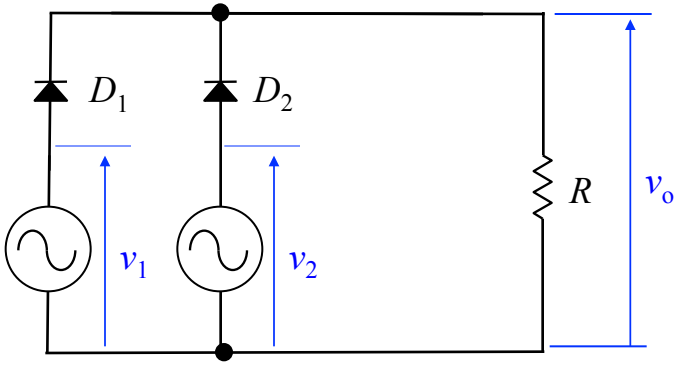
(a) $v_1 = +10$ V



(b) $v_1 = -10$ V

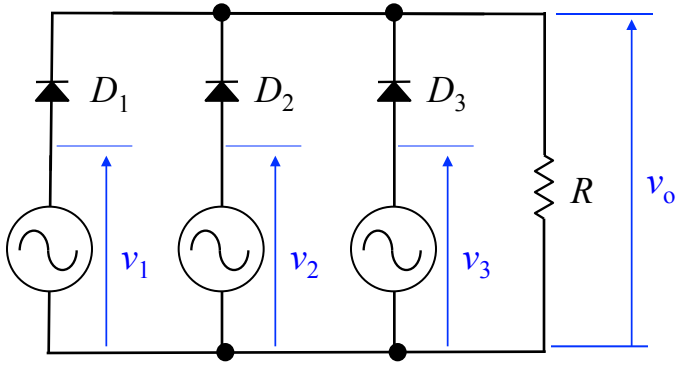
Operating modes of the bridge rectifier

STEP 1. Problem 2 Draw the waveforms of output voltage v_o of the rectifiers below. What are the average voltages of v_o? Assume that the diode characteristics are simplified ones.



$$v_1 = V \sin \omega t$$
$$v_2 = V \cos \omega t$$

(a) 2-phase rectifier



$$v_1 = V \sin \omega t$$
$$v_2 = V \sin\left(\omega t - \frac{2\pi}{3}\right)$$
$$v_3 = V \sin\left(\omega t - \frac{4\pi}{3}\right)$$

(b) 3-phase rectifier