# EE-222: Microprocessor Systems
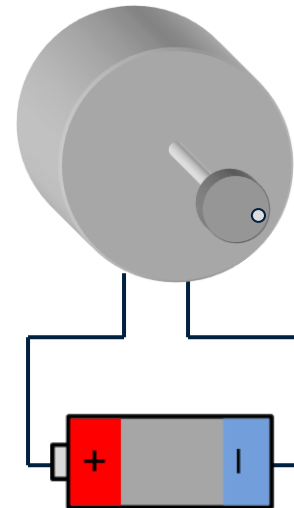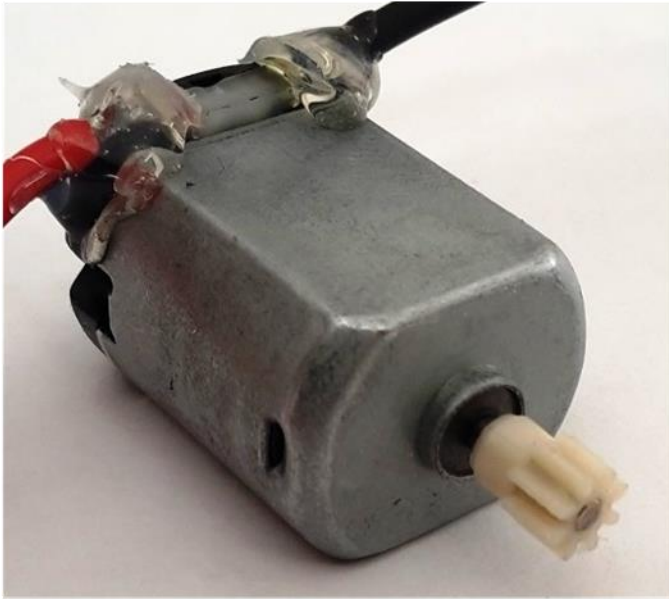
## Programming AVR ADC

Instructor: Dr. Arbab Latif

SCHOOL OF ELECTRICAL ENGINEERING &
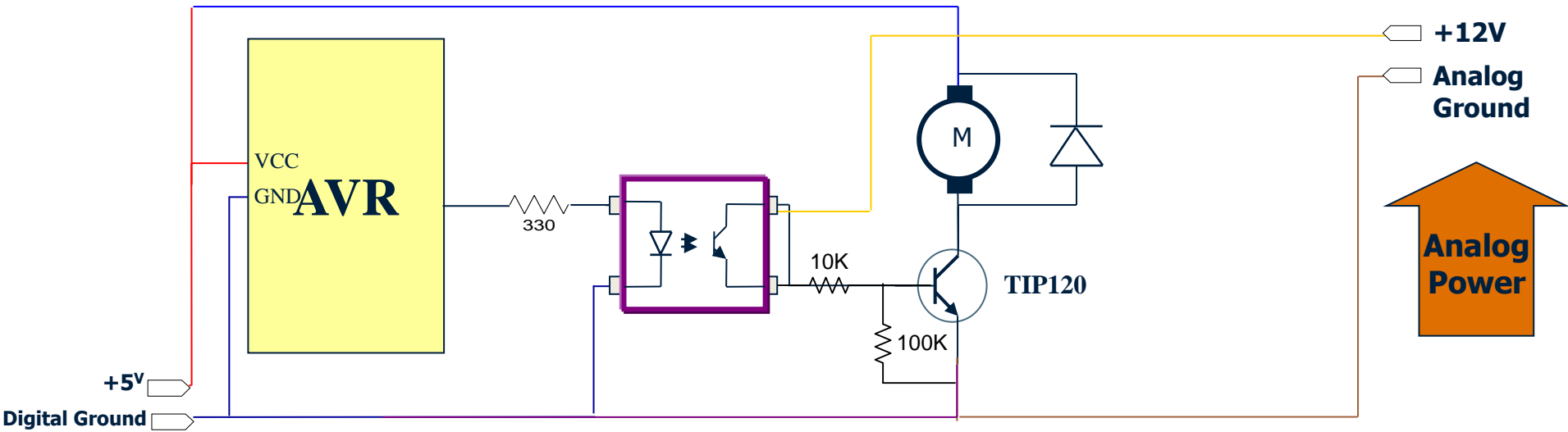COMPUTER SCIENCE (SEECS)

# Topics

- Making Robots with Motors
- DC motor
  - Unidirectional control
  - Bidirectional control
- PWM modes
  - Wave generating using Fast PWM
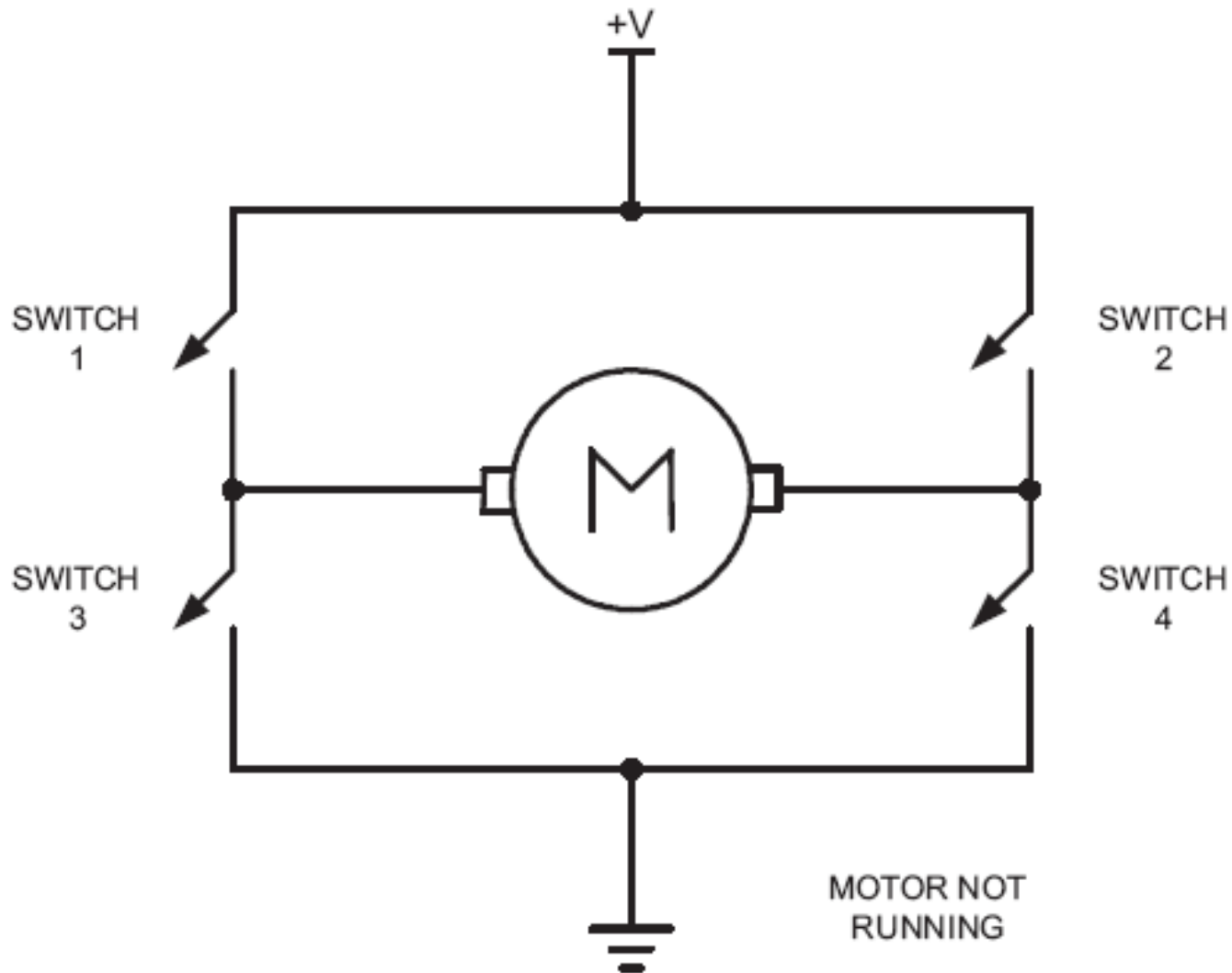  - Wave generating using Phase correct PWM

# DC motor

# Unidirectional control
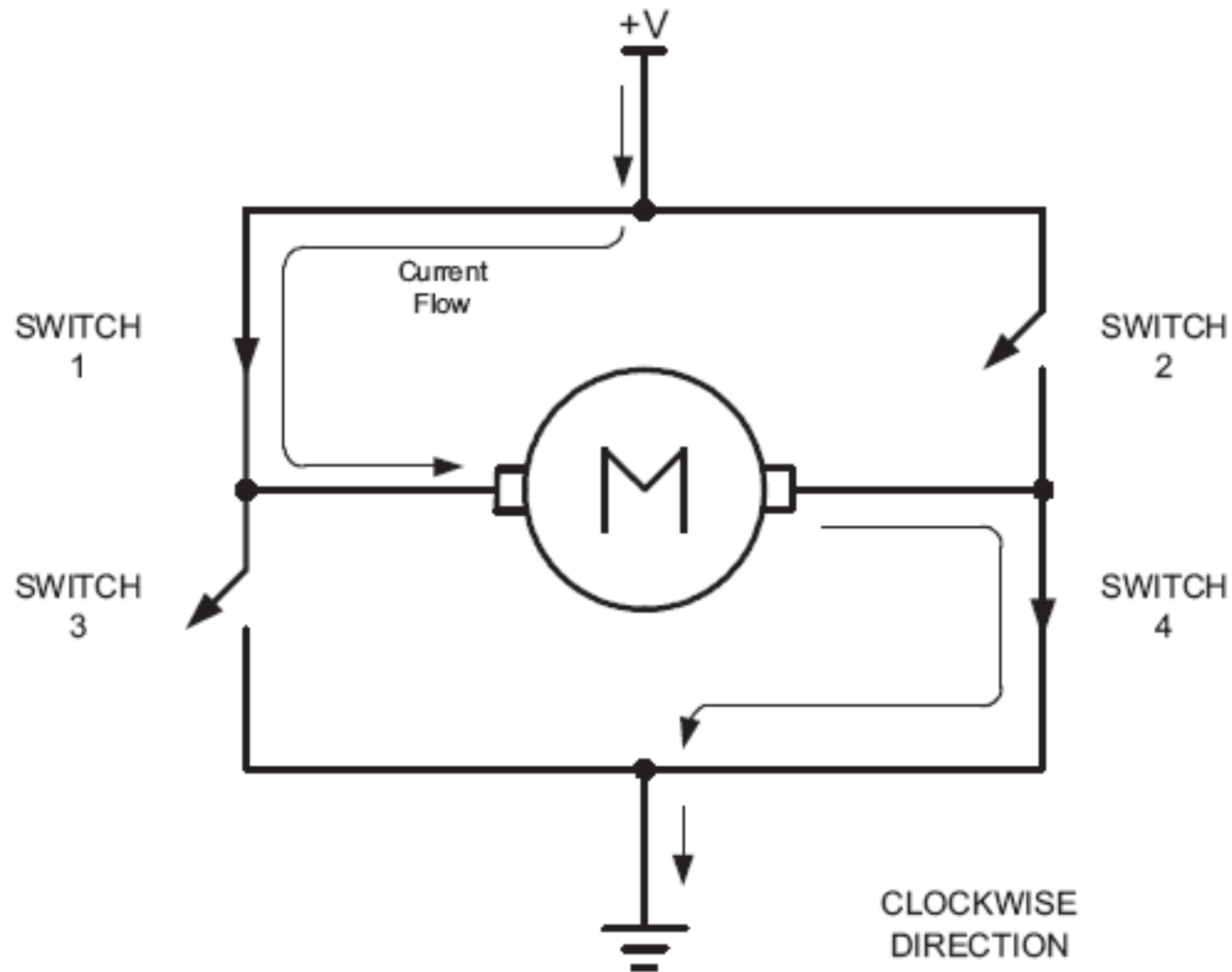


VCC

GND **AVR**

330

10K

100K

TIP120

M

+12V

Analog
Ground

**Analog
Power**

+5ᵛ

Digital Ground

# Bidirectional control

# Bidirectional (clock wise)



+V

SWITCH 1

SWITCH 2

Current Flow

M

SWITCH 3

SWITCH 4

CLOCKWISE DIRECTION

# Bidirectional (counter clockwise)



+V

Current Flow

SWITCH 1

SWITCH 2

M

SWITCH 3

SWITCH 4

COUNTER CLOCKWISE DIRECTION
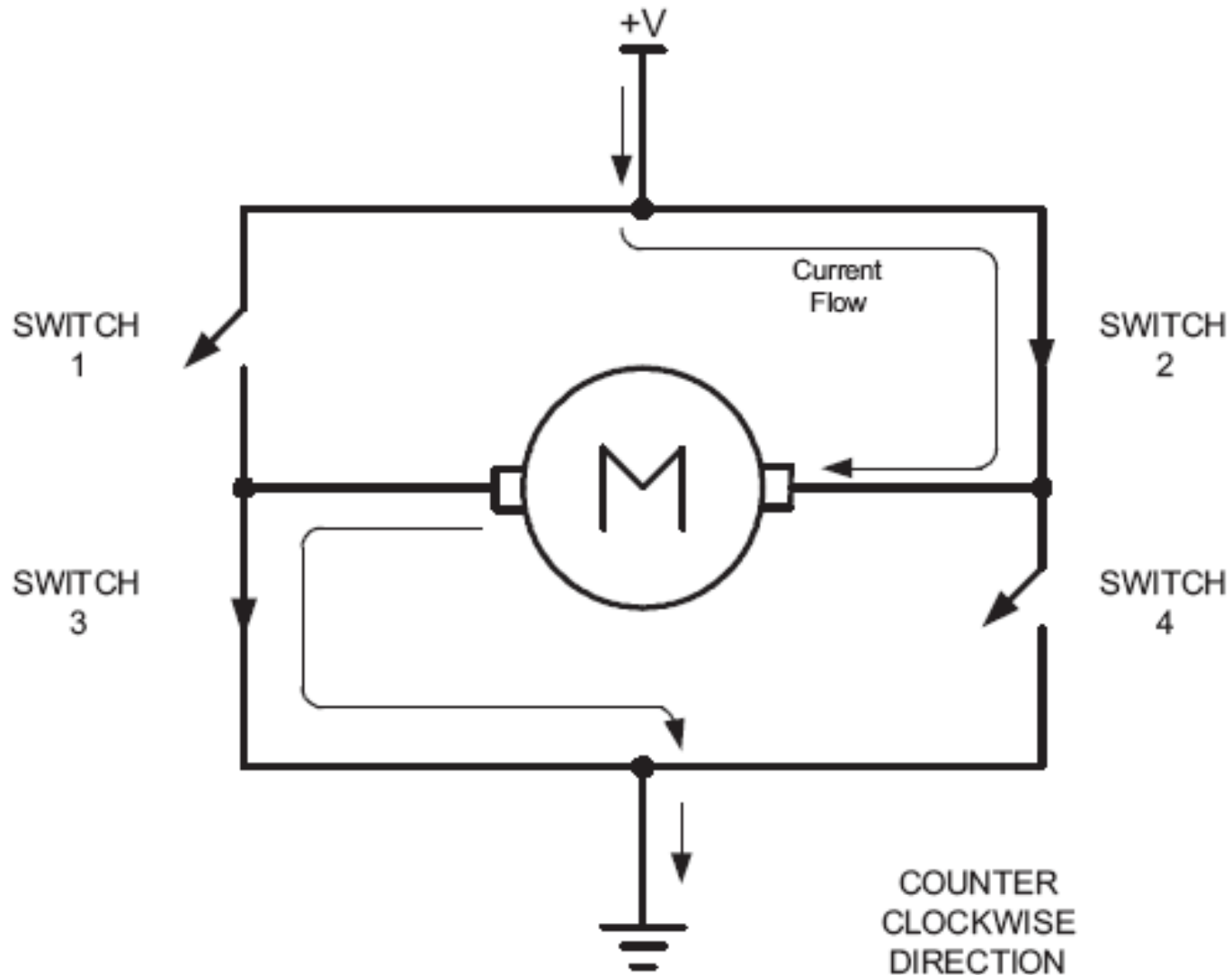
# Bidirectional
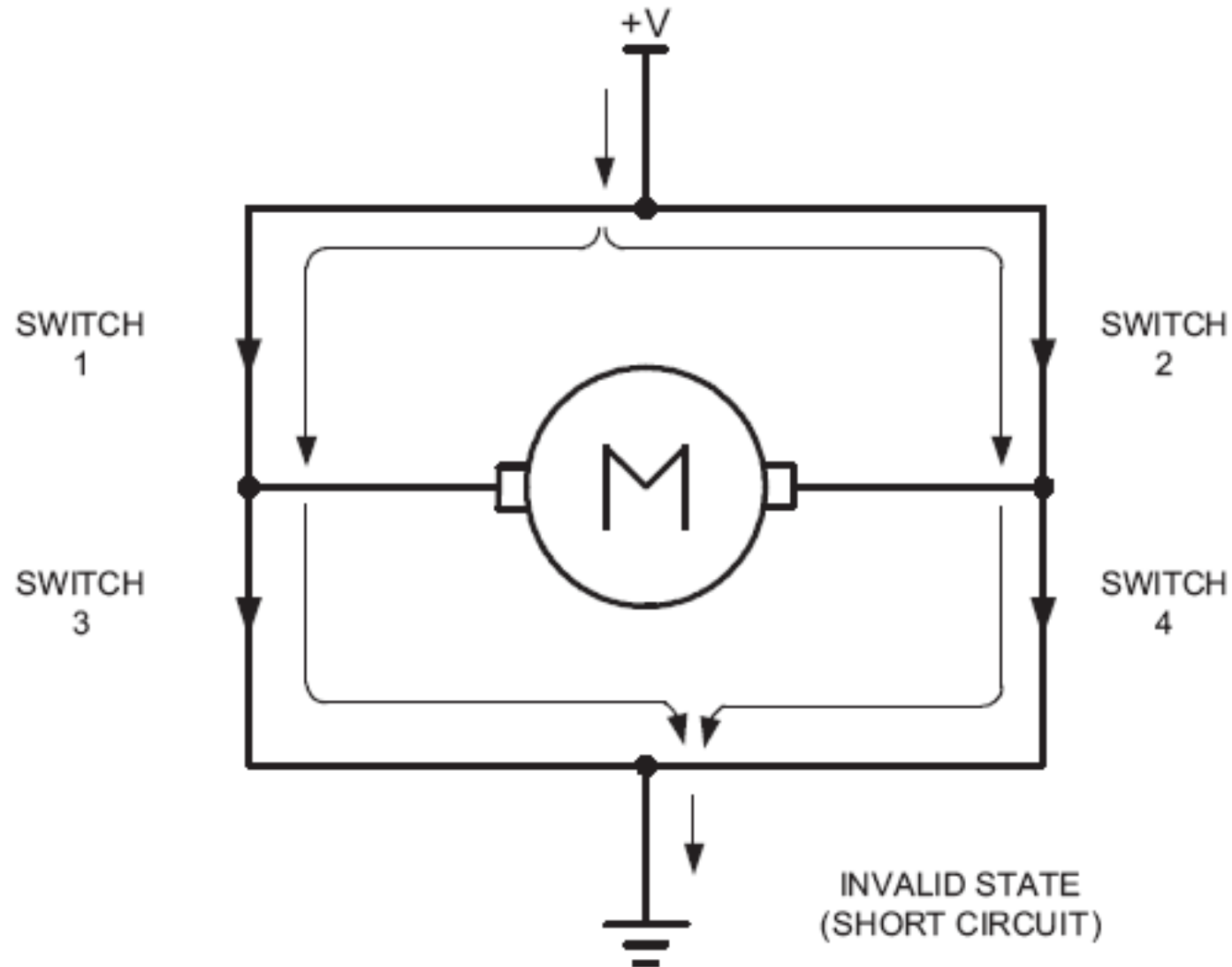
# L298 module

# PWM and Duty Cycle



¼ POWER    25% DC

½ POWER    50% DC

¾ POWER    75% DC

FULL  POWER    100% DC
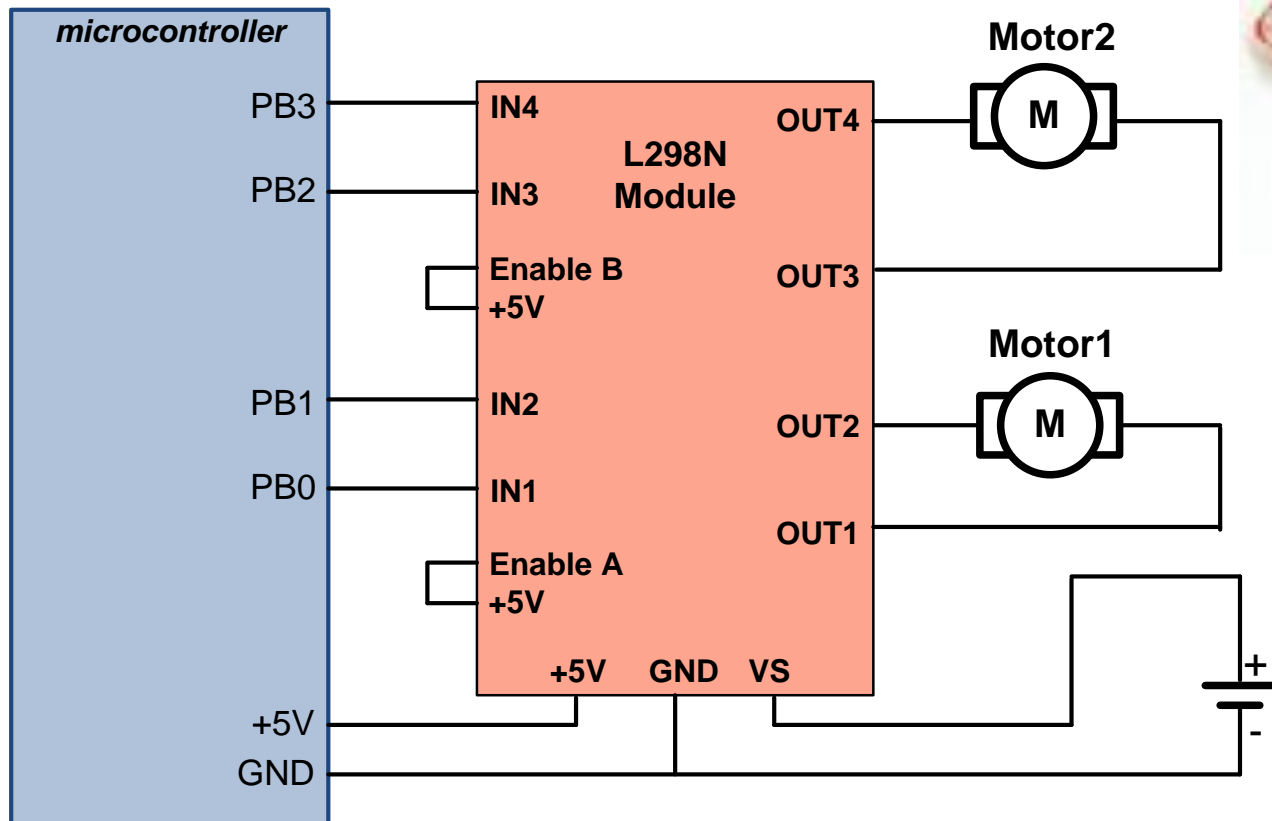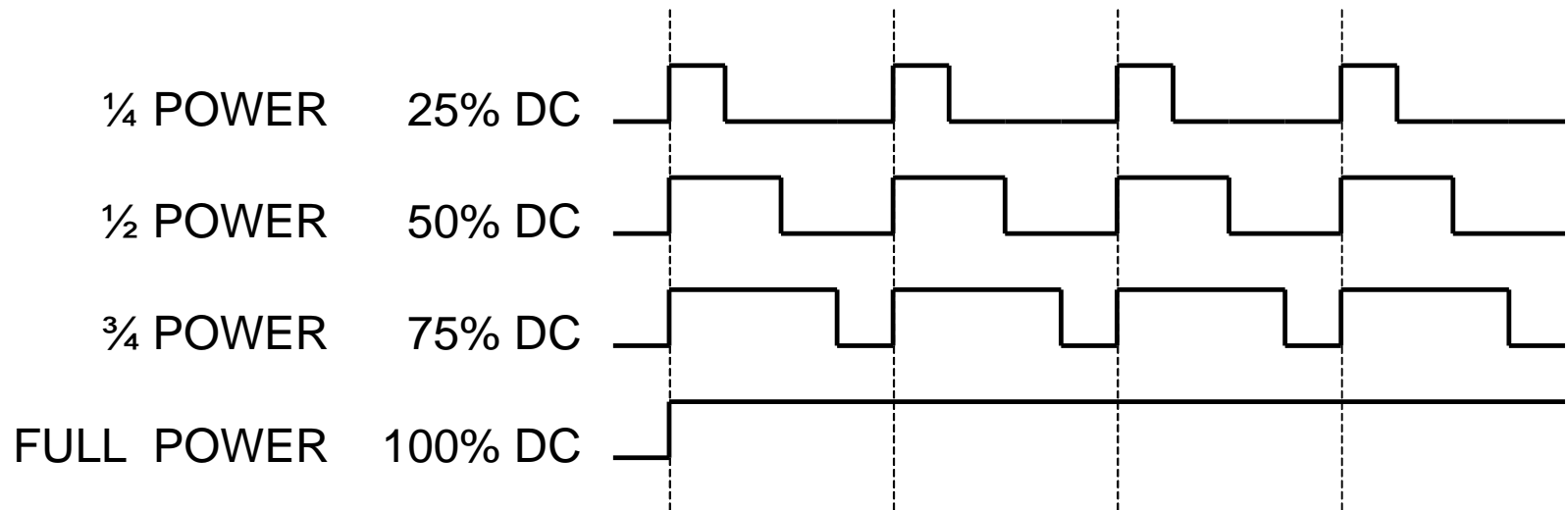
# Timer0 Review



| COM0A1 | COM0A0 | COM0B1 | COM0B0 | - | - | WGM01 | WGM00 | TCCR0A |
|--------|--------|--------|--------|---|---|-------|-------|--------|

| FOC0A | FOC0B | - | - | WGM02 | CS02 | CS01 | CS00 | TCCR0B |
|-------|-------|---|---|-------|------|------|------|--------|

| COM0A1 | COM0A0 | COM0B1 | COM0B0 | - | - | WGM01 | WGM00 | TCCR0A |

| FOC0A | FOC0B | - | - | WGM02 | CS02 | CS01 | CS00 | TCCR0B |

**Timer Mode (WGM)**
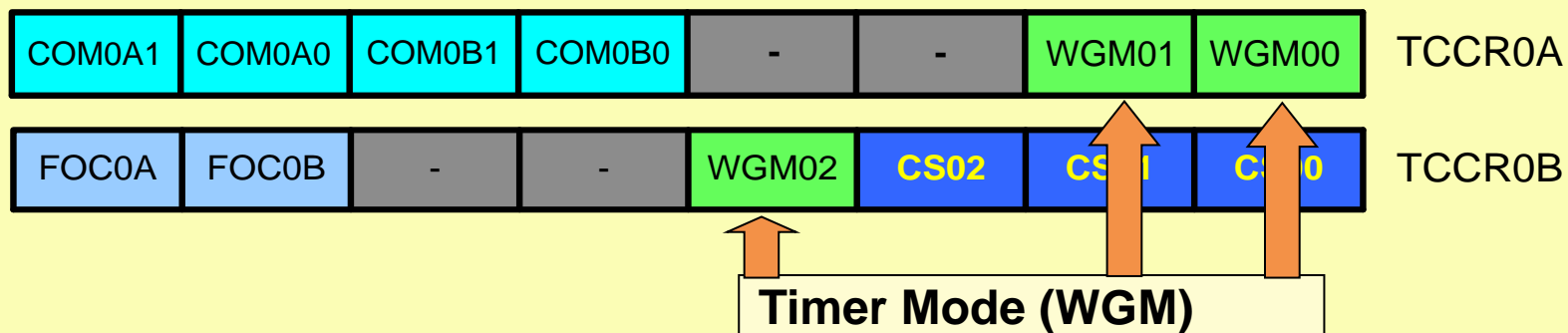
| WGM02 | WGM01 | WGM00 | Comment |
|-------|-------|-------|---------|
| 0 | 0 | 0 | Normal |
| 0 | 0 | 1 | Phase correct PWM |
| 0 | 1 | 0 | CTC (Clear Timer on Compare Match) |
| 0 | 1 | 1 | Fast PWM |
| 1 | 0 | 0 | Reserved |
| 1 | 0 | 1 | Phase correct PWM |
| 1 | 1 | 0 | Reserved |
| 1 | 1 | 1 | Fast PWM |

# Fast PWM mode

- Similar to Normal mode but OCR0x are buffered.

TCNT0  **TOV0:** $\boxed{1}$

0xFF ----------

TOV  TOV  TOV

0  time

**TCNT0**

**TOV0**  **=** → **OCF0x**

**OCR0x**

TOV0

**OCR0x-BUF**

0  1  2 ---> FE  FF

TOV0 = 1
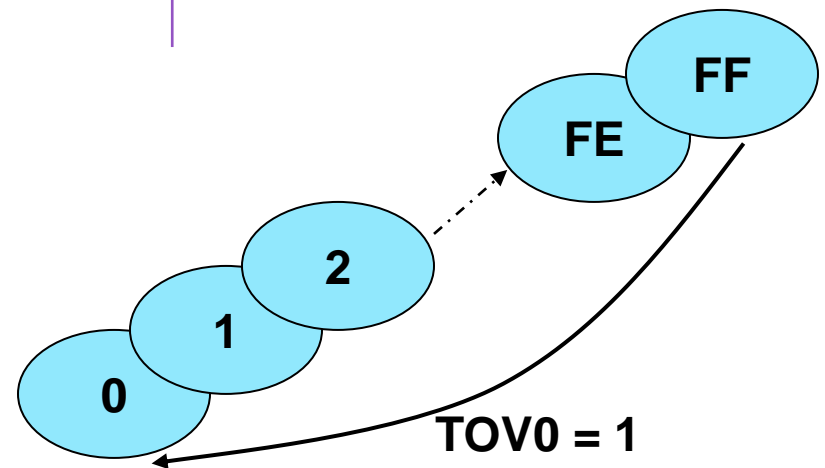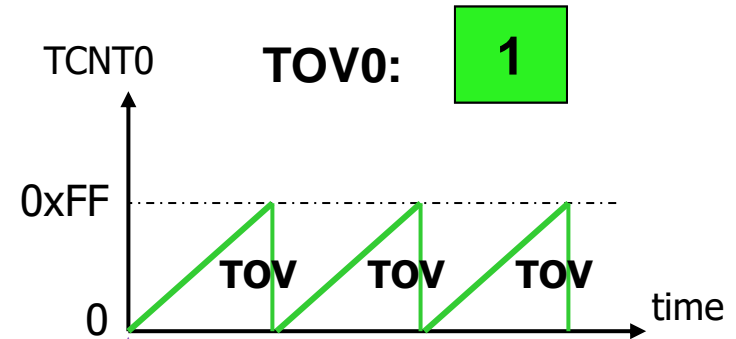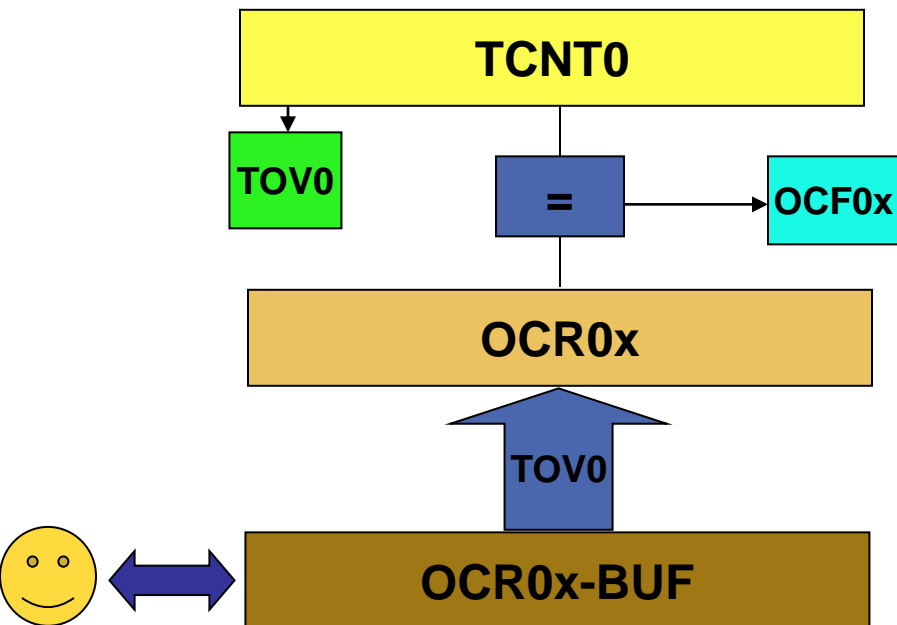
# Phase Correct PWM mode

- Goes up and down like a yo-yo
- When TCNT becomes zero, the TOV0 flag sets.

TCNT0    **TOV0:**    **1**

0xFF

0    **TOV**    time

TCNT0

TOV0

= → OCF0x

OCR0x

TCNT0=0xFF

OCR0x-BUF

FF

FE

2

1

0    **TOV0 = 1**

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| FOC0A | FOC0B | - | - | WGM02 | CS02 | CS01 | CS00 | TCCR0B |

| COM0A1 | COM0A0 | COM0B1 | COM0B0 | - | - | WGM01 | WGM00 | TCCR0A |

## Compare Output Mode (COM)

### CTC or Normal (Non PWM)

| COM0x1 | COM0x0 | Description |
|--------|--------|-------------|
| 0 | 0 | Normal port operation, OC0 disconnected |
| 0 | 1 | Toggle OC0 on compare match |
| 1 | 0 | Clear OC0 on compare match |
| 1 | 1 | Set OC0 on compare match |

### Fast PWM

| COM0x1 | COM0x0 | Description |
|--------|--------|-------------|
| 0 | 0 | Normal port operation, OC0 disconnected |
| 0 | 1 | Reserved |
| 1 | 0 | Clear OC0 on compare match, set OC0 at TOP. |
| 1 | 1 | Set OC0 on compare match, clear OC0 at TOP. |

### Phase Correct PWM

| COM0x1 | COM0x0 | Description |
|--------|--------|-------------|
| 0 | 0 | Normal port operation, OC0 disconnected |
| 0 | 1 | Reserved |
| 1 | 0 | Clear OC0 on compare match when up-counting. Set OC0 on compare match when down-counting. |
| 1 | 1 | Set OC0 on compare match when up-counting. Clear OC0 on compare match when down-counting. |

# Fast PWM Calculations

**Fast PWM**
**Duty cycle = changeable (0% to 100%)**
**Frequency = selectable between limited choices**

TCNT0

0xFF

OCR0x

0

OC0x

COM=2

OC0x

COM=3

TCNT0

0xFF

OCR0x

0

OC0x

COM=2

OC0x

COM=3
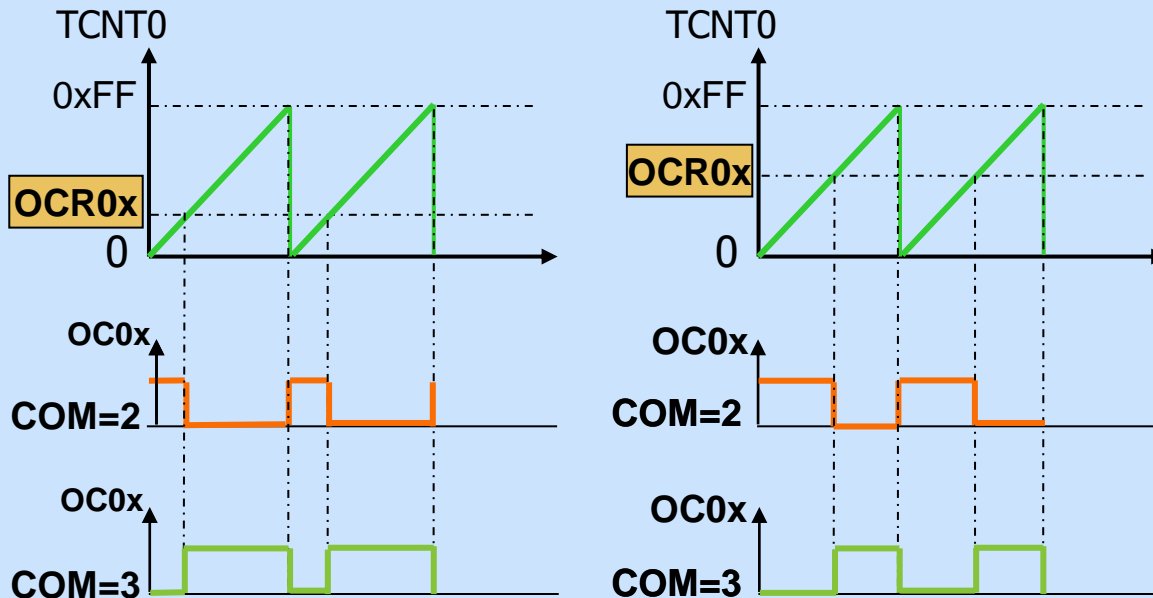
$$Duty\ Cycle = \frac{OCR0 + 1}{256} \times 100$$

$$Duty\ Cycle = \frac{255 - OCR0}{256} \times 100$$

$$F_{OC0} = \frac{f_{clk}}{N(256)}$$

$$F_{OC0} = \frac{f_{clk}}{N(256)} \implies 62.500\text{KHz} = \frac{16\text{MHz}}{N(256)} \implies N = \frac{16\text{MHz}}{62.500\text{K}*256} = 1$$

75/100 = (OCR0x+1)/256 ➜ OCR0x+1 = 192 ➜ OCR0x = 191

```
DDRD |= (1<<6); //PD6 as output
OCR0A = 191;
TCCR0A = (1<<COM0A1)|(1<<WGM01)|(1<<WGM00);
TCCR0B = 0x01; //N = 1 (no prescaler)
```

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| FOC0A | FOC0B | - | - | WGM02 | CS02 | CS01 | CS00 | TCCR0B |

| COM0A1 | COM0A0 | COM0B1 | COM0B0 | - | - | WGM01 | WGM00 | TCCR0A |

## Compare Output Mode (COM)

### CTC or Normal (Non PWM)

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| 0 | 0 | Normal port operation, OC0 disconnected |
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### Phase Correct PWM

| COM0x1 | COM0x0 | Description |
|--------|--------|-------------|
| 0 | 0 | Normal port operation, OC0 disconnected |
| 0 | 1 | Reserved |
| 1 | 0 | Clear OC0 on compare match when up-counting. Set OC0 on compare match when down-counting. |
| 1 | 1 | Set OC0 on compare match when up-counting. Clear OC0 on compare match when down-counting. |

# Phase Correct PWM Calculations

**Phase Correct PWM**
**Duty cycle = changeable (0% to 100%)**
**Frequency = selectable between limited choices**
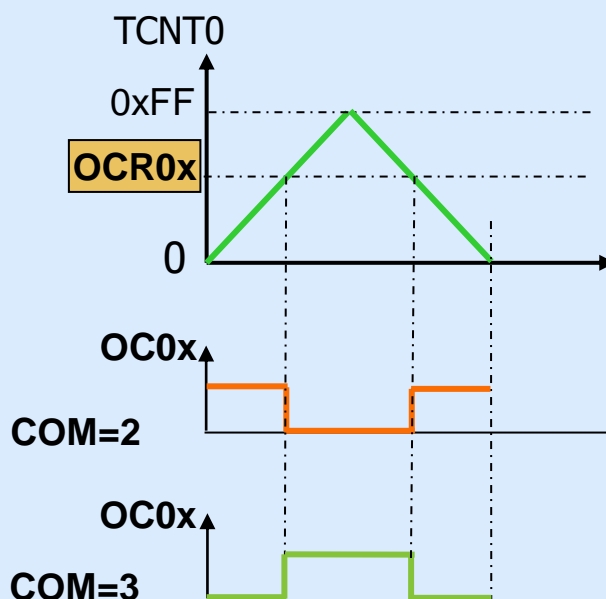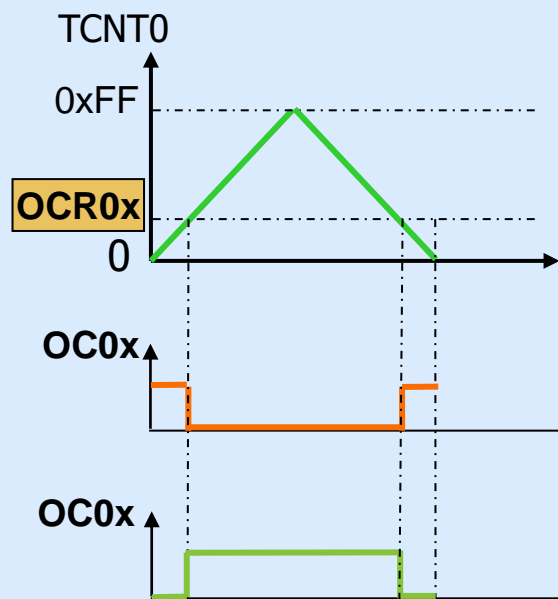


$$\text{Duty Cycle} = \frac{OCRx}{255} \times 100$$

$$\text{Duty Cycle} = \frac{255 - OCR0}{255} \times 100$$

$$F_{OC0} = \frac{f_{clk}}{N(510)}$$

# Assuming XTAL = 16 MHz, make the following wave:
## duty cycle = 75% and frequency = 31.372KHz

$$F_{OC0} = \frac{f_{clk}}{N(510)} \implies 31.372KHz = \frac{16MHz}{N(510)} \implies N = \frac{16MHz}{31.372K*510} = 1$$

$75/100 = OCR0x / 255 \implies OCR0x = 191$

```
DDRD |= (1<<6); //PD6 as output
OCR0A = 191;
TCCR0A = (1<<COM0A1)|(1<<WGM00);
TCCR0B = 0x01; //N = 1 (no prescaler)
```