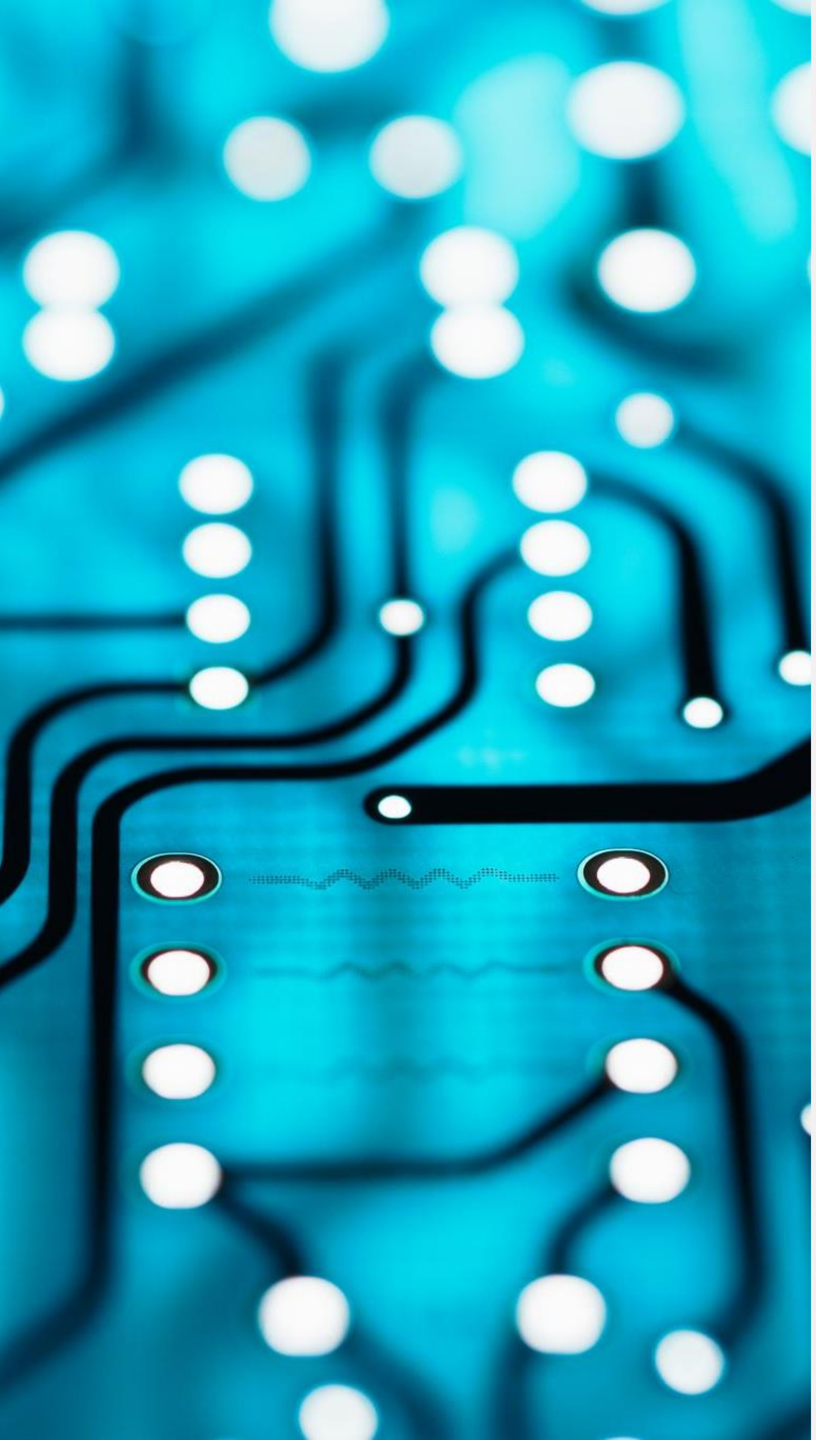
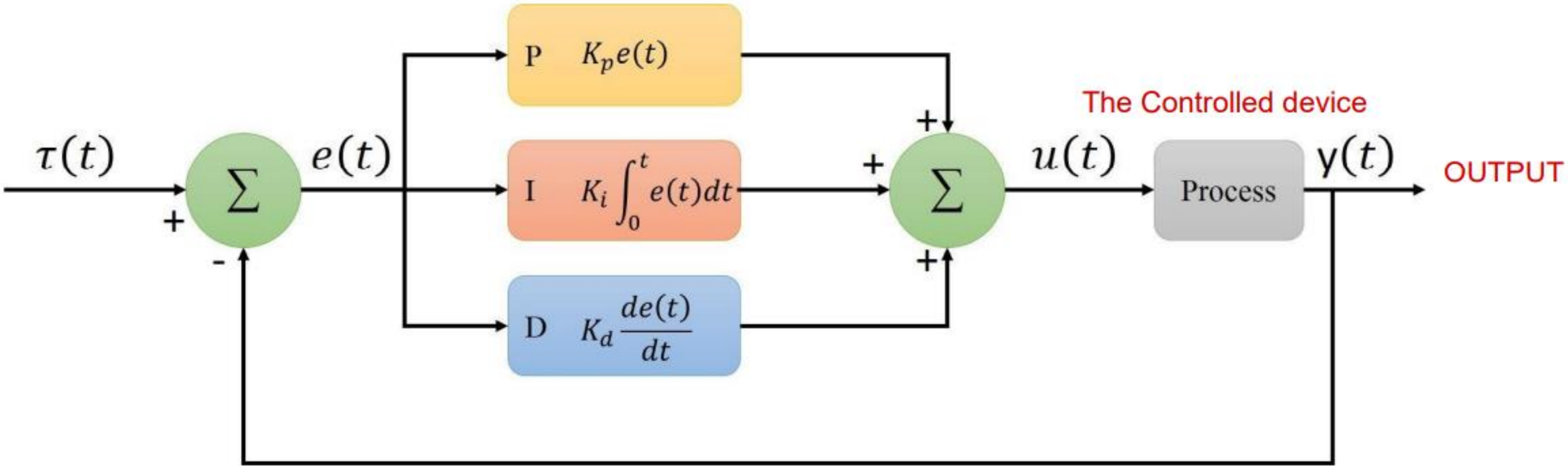


Embedded Systems (EPM)

Lecture (10) Summary

PID-Controller



$$u(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt}$$

1- Proportional term: $K_p e(t)$

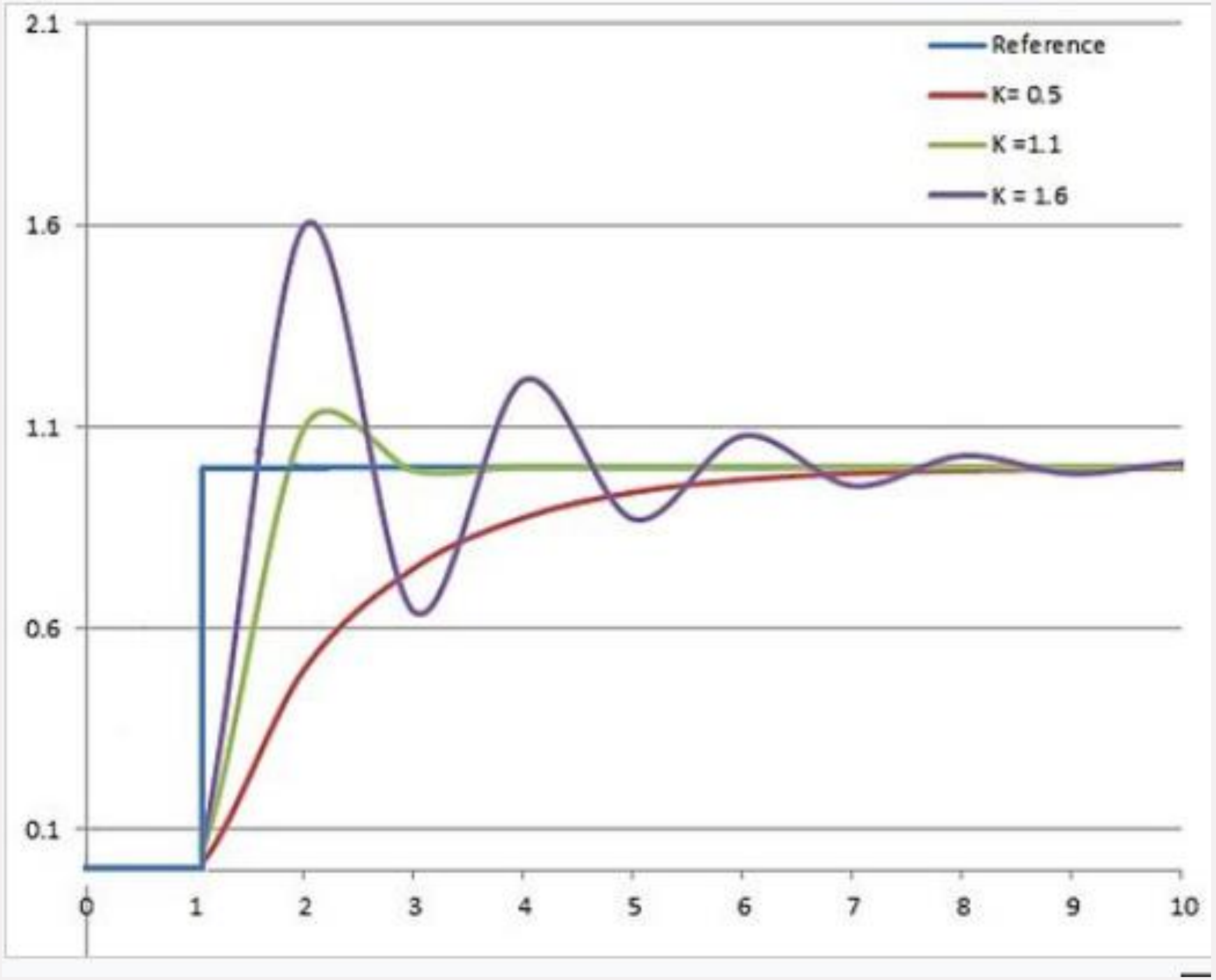
produces an output value that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant Kp, called the proportional gain constant.

A high proportional gain results in a large change in the output for a given change in the error. If the proportional gain is too high, the system can become unstable.

a small gain results in a small output response to a large input error.

If the proportional gain is too low, the control action may be too small when responding to system disturbances

By Changing the values of Kp at const Ki , Kd:



2- Integral term: $K_i \int_0^t e(t)dt$

The integral in a PID controller is the sum of the instantaneous error over time and gives the accumulated offset that should have been corrected previously.

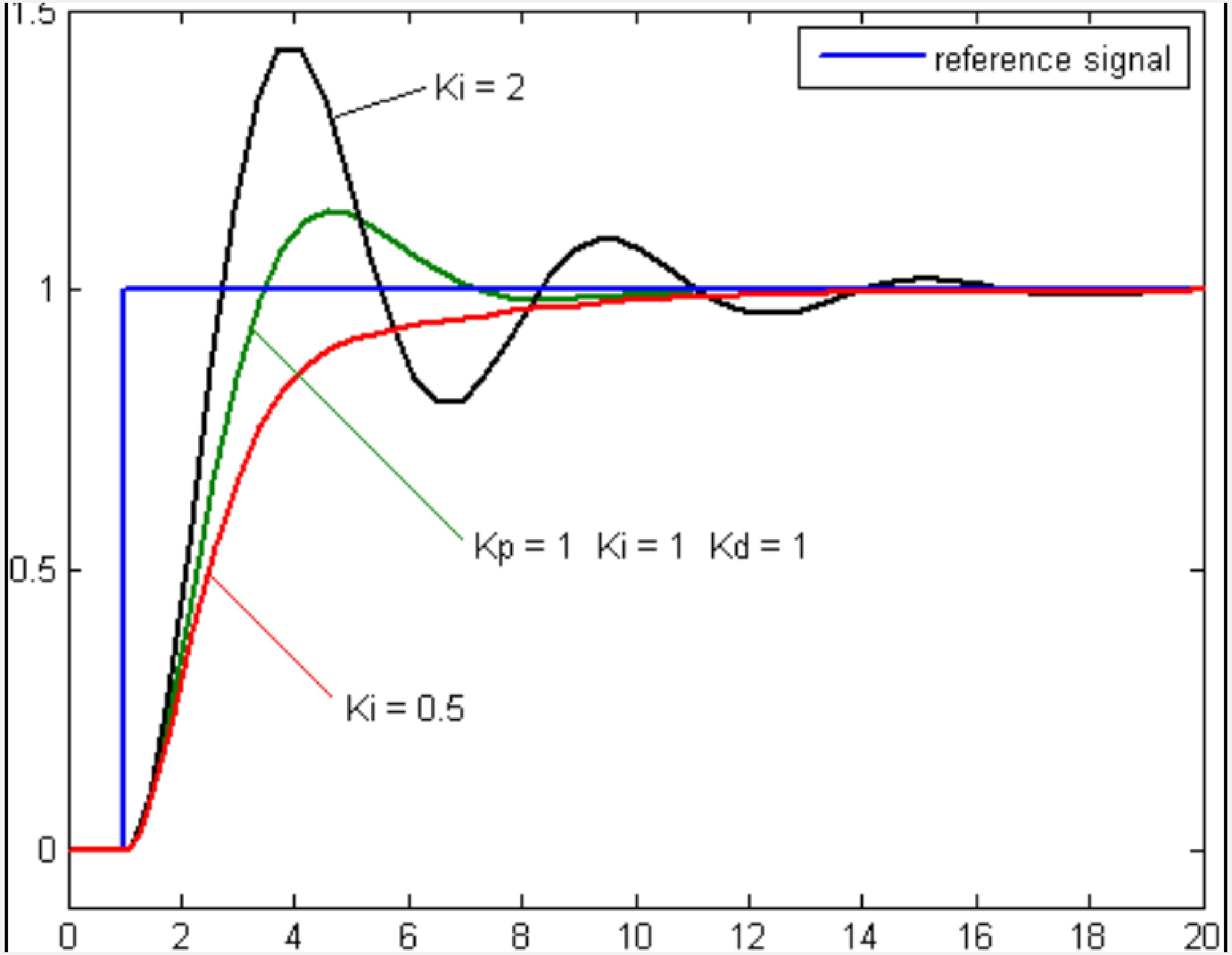
It's proportional to both the magnitude of the error and the duration of the error.

The accumulated error is then multiplied by the integral gain (Ki) and added to the controller output.

It accelerates the movement of the process towards setpoint and eliminates the residual steady-state error that occurs with a pure proportional controller.

since the integral term responds to accumulated errors from the past, it can cause the present value to overshoot the setpoint value

By Changing the values of Ki at const Kp, Kd:

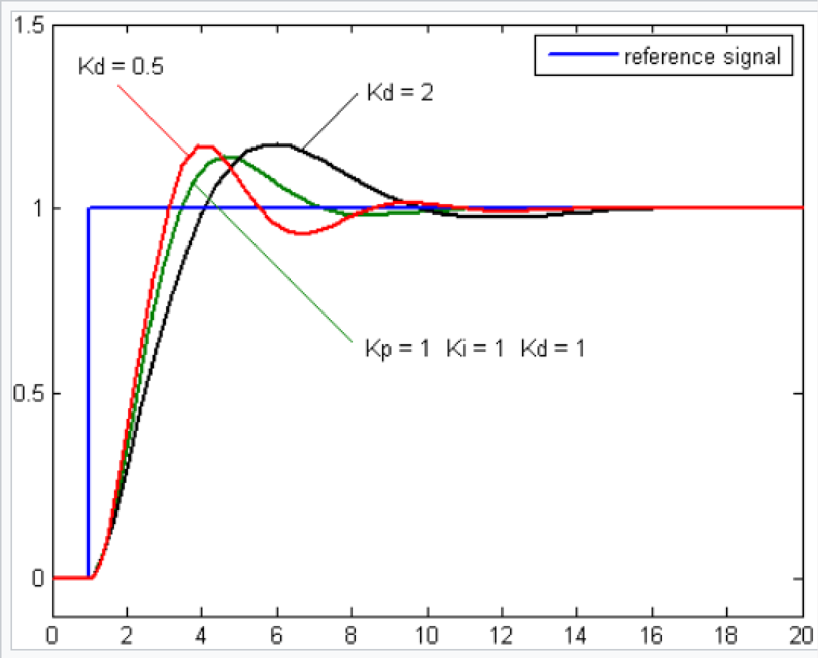


3- Proportional term: $K_d \frac{de(t)}{dt}$

it is calculated by determining the slope of the error over time and multiplying this rate of change by the derivative gain Kd.

It predicts system behavior and thus improves settling time and stability of the system.

By Changing the values of Kd at const Kp , Ki:



Realization of PID

```
float r=50;
float ui,up,ud;
float ui_old;
float e;
float e_old;
float u;
float Kp=5; float Ki=0; float Kd=0;
void loop(void) {
    float h=read_val();
    e=r-h;
    up=Kp*e;
    ui=ui+Ki*e;
    ud=Kd*(e-e_old);
    u=up+ui+ud;
    e_old=e;
    set_val(u);
    delay(10);
}
```

Reading Output Value

Comparing it to the set point

Control based on proportional action

integral action

diffrential action

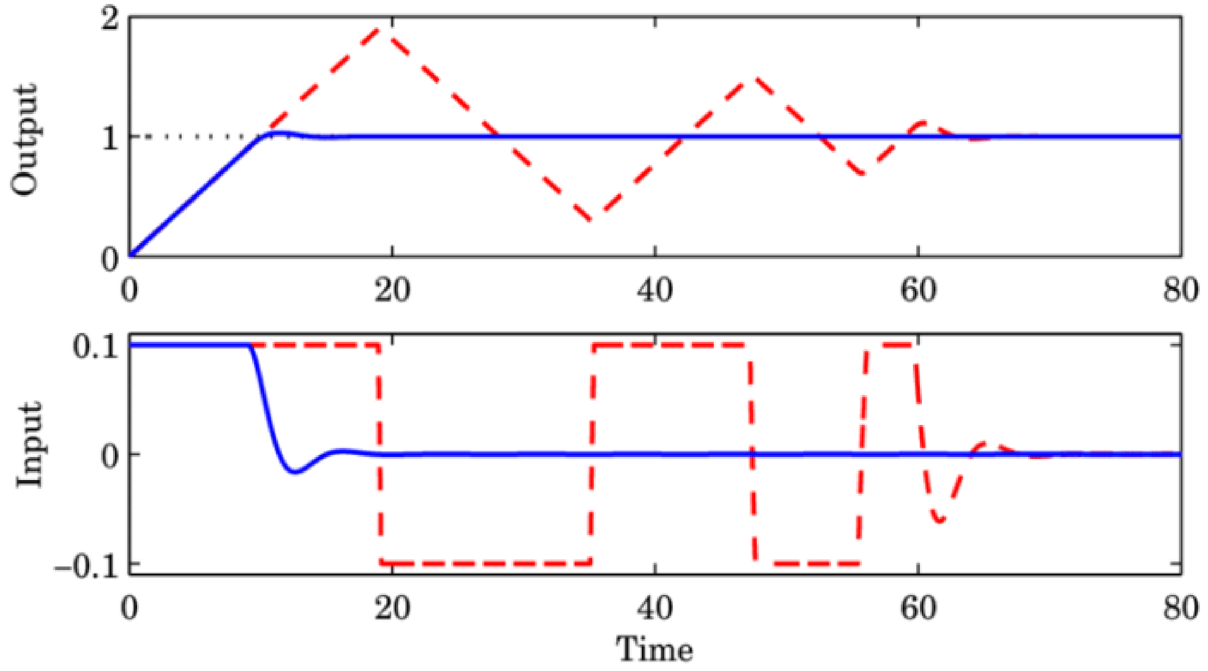
Total action on system

and repeat the loop

Realization of PID With (Anti-windup)

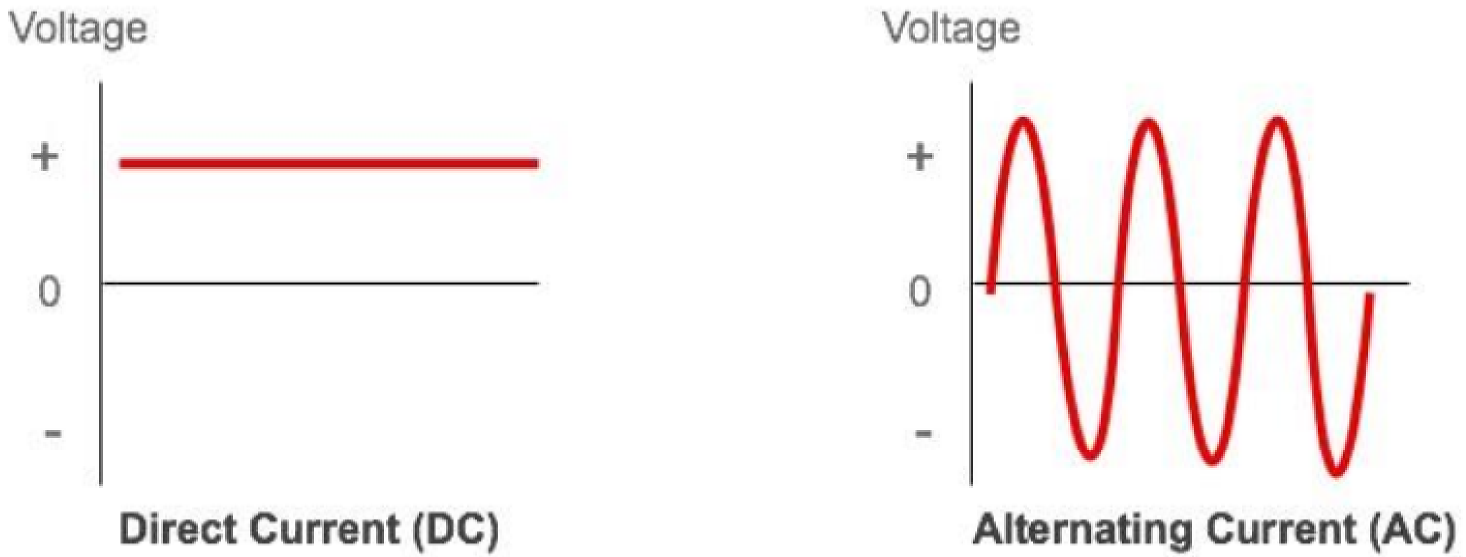
```
float r=50;
float ui,up,ud;
float ui_old;
float e;
float e_old;
float u;
float Kp=30; float Ki=0.75; float Kd=20;
#define MAX_U 100
#define MIN_U 0
void loop(void) {
    float h=read_val();
    e=r-h;
    up=Kp*e;
    ui=ui+Ki*e;
    ud=Kd*(e-e_old);
    u=up+ui+ud;
    if ( (u>MAX_U) || (MIN_U<0) ) {
        ui=ui_old;
        u=up+ui+ud;
    }
    e_old=e;
    ui_old=ui;
    set_val(u);
    if (digitalRead(SET_POINT_PIN)==0)  r=get_set_point();
    delay(10);
}
```

u < MIN_U



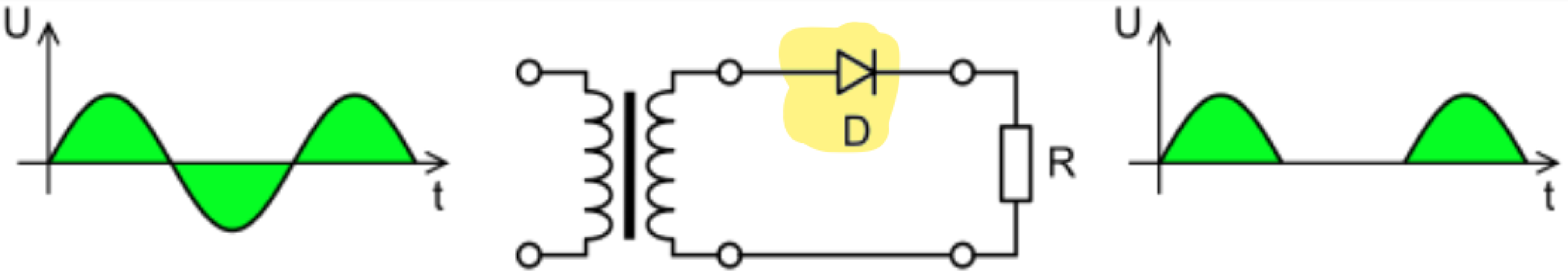
Rectifier

- A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction.



Rectifier

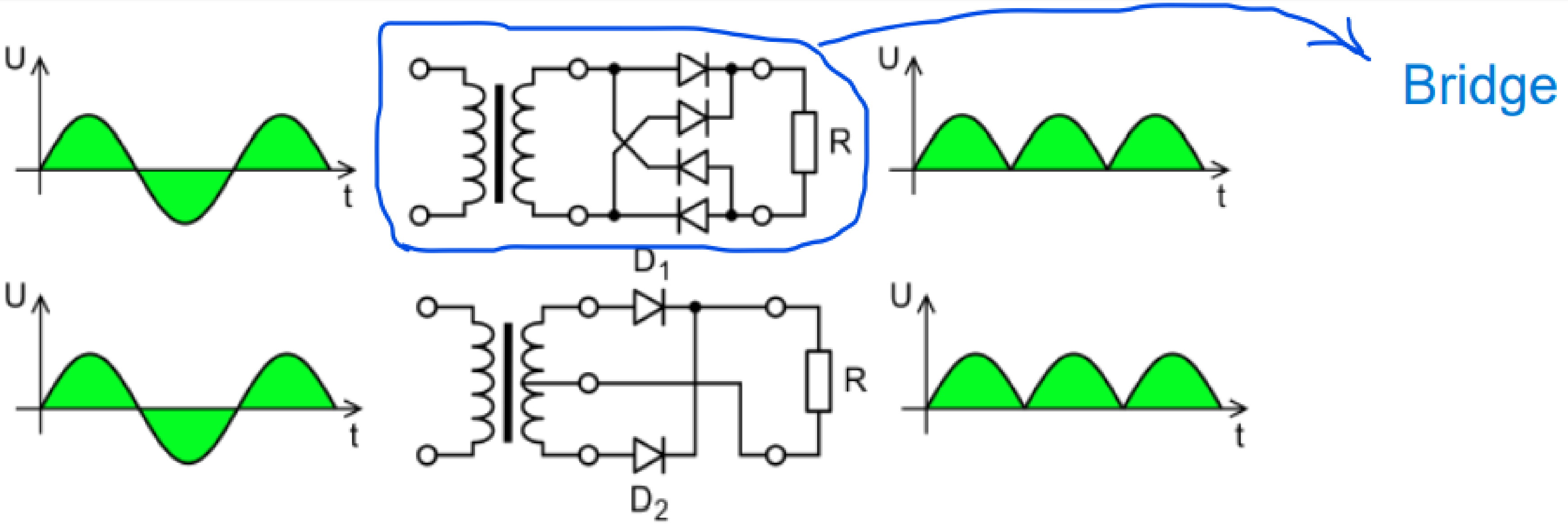
Single-phase rectifiers (Half-wave rectification)



- In half-wave rectification of a single-phase supply, either the positive or negative half of the AC wave is passed, while the other half is blocked. Because only one half of the input waveform reaches the output, mean voltage is lower. Half-wave rectification requires a single diode in a single-phase supply

Rectifier

Single-phase rectifiers (Full-wave rectification)

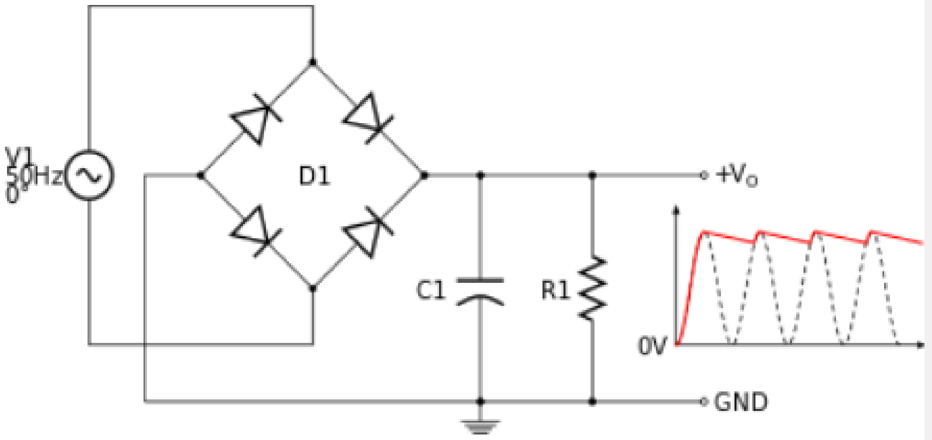


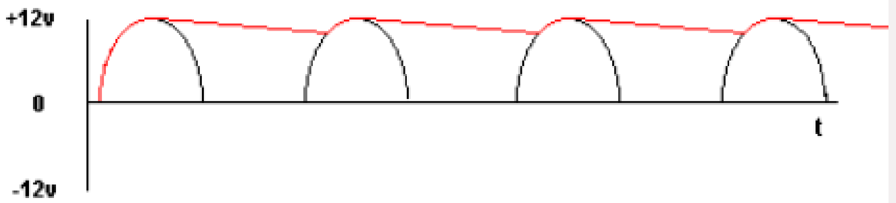
- A full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output. Mathematically, this corresponds to the absolute value function.
- Full-wave rectification converts both polarities of the input waveform to pulsating DC (direct current), and yields a higher average output voltage.

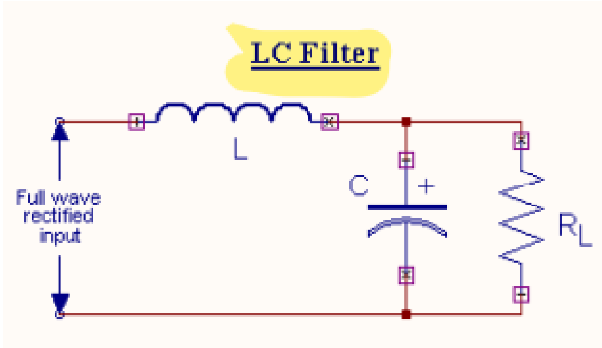
Rectifier

Output smoothing (Filtering)

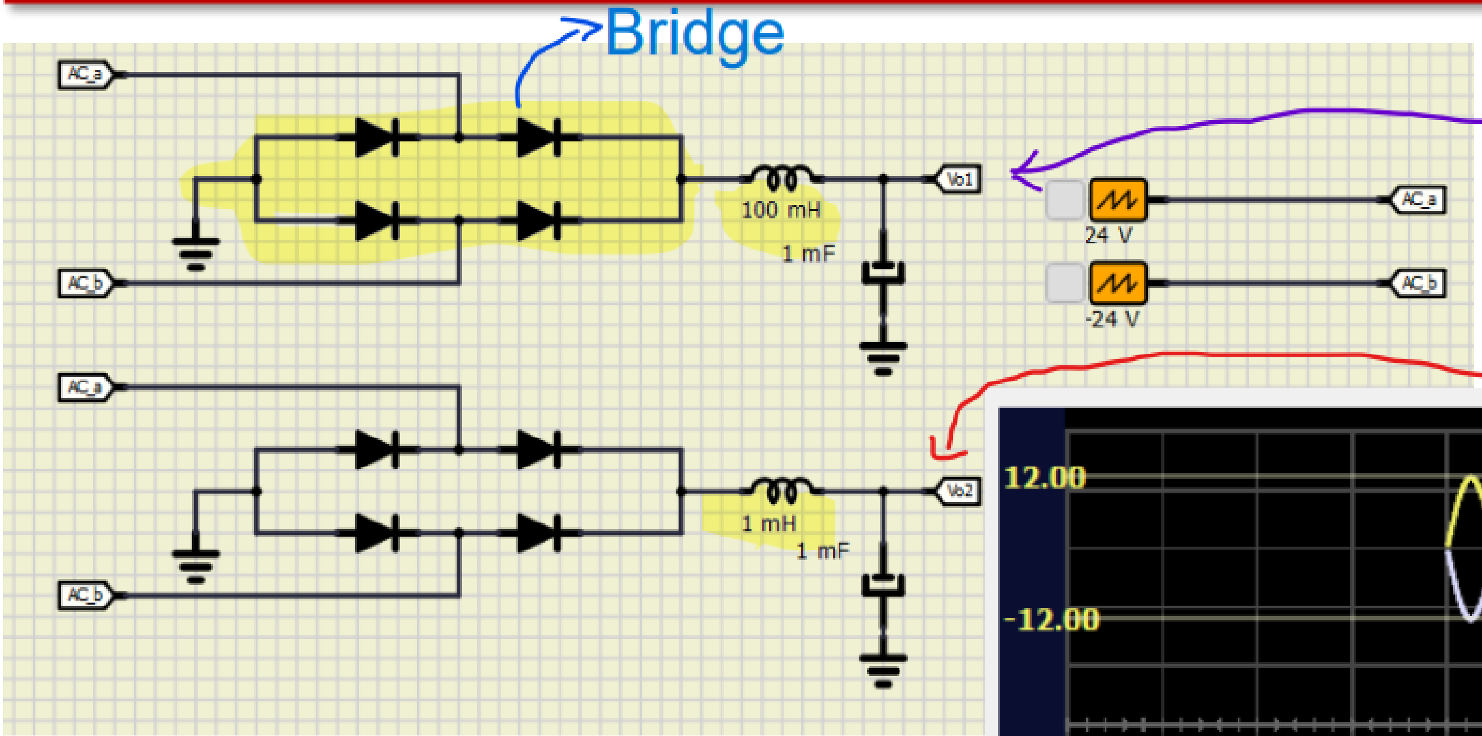
- While half-wave and full-wave rectification deliver unidirectional current, neither produces a constant voltage.
- There is a large AC ripple voltage component at the source frequency for a half-wave rectifier, and twice the source frequency for a full-wave rectifier.
- Ripple voltage is usually specified peak-to-peak.
- Producing steady DC from a rectified AC supply requires a smoothing circuit or filter. In its simplest form this can be just a capacitor (also called a **filter**, reservoir, or **smoothing capacitor**)

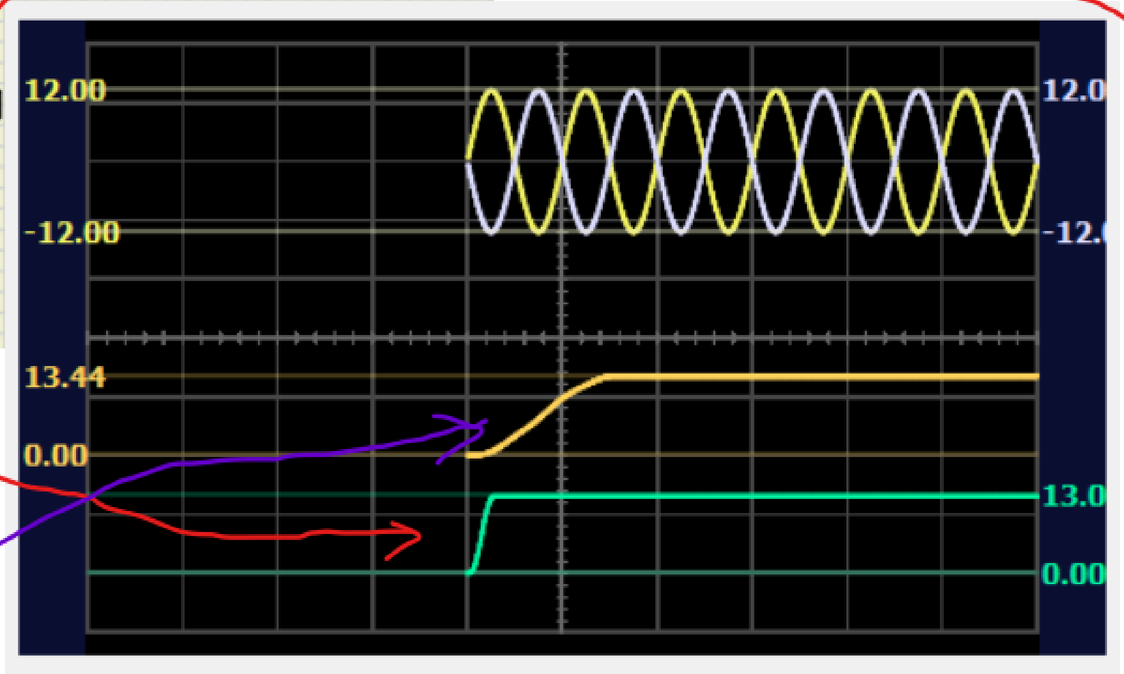


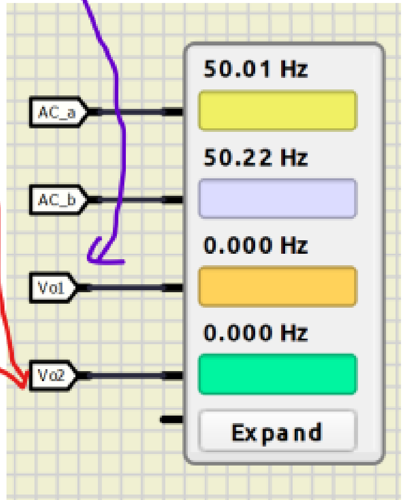




Effect of small/large cutoff frequency

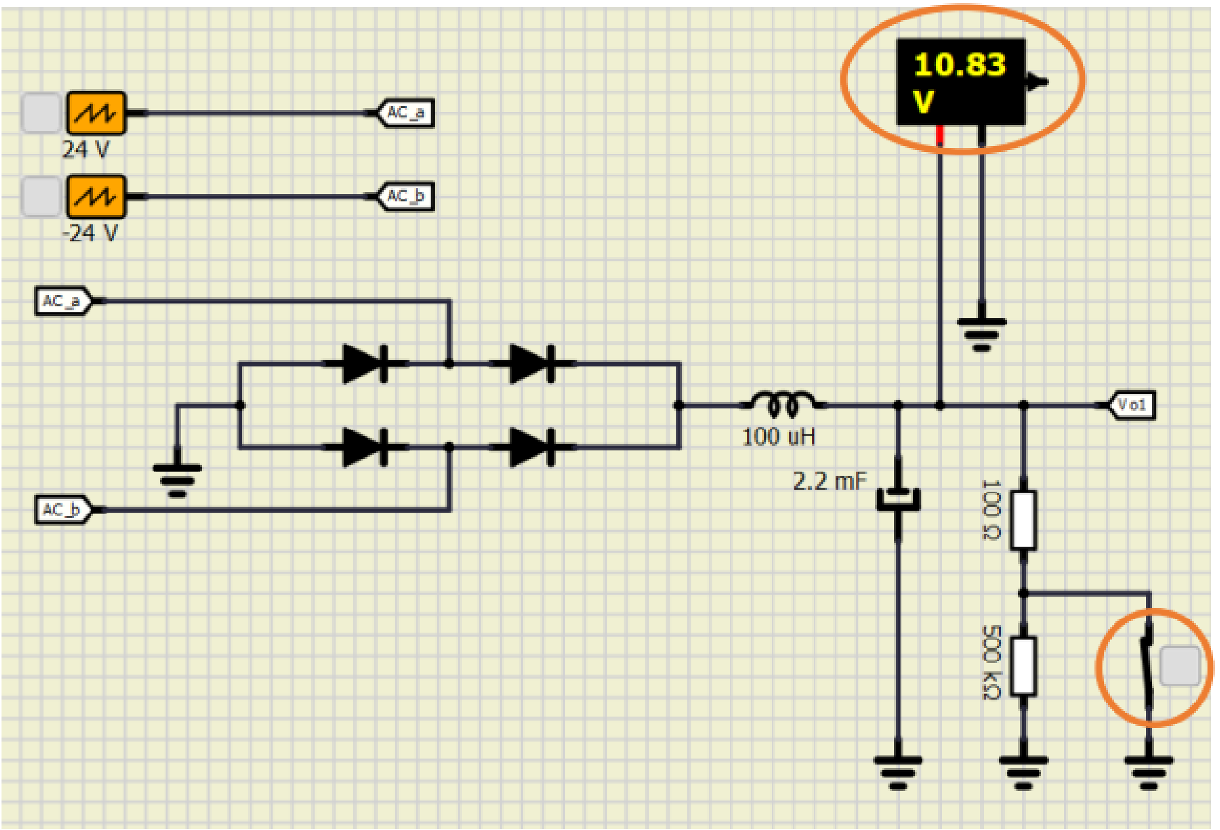


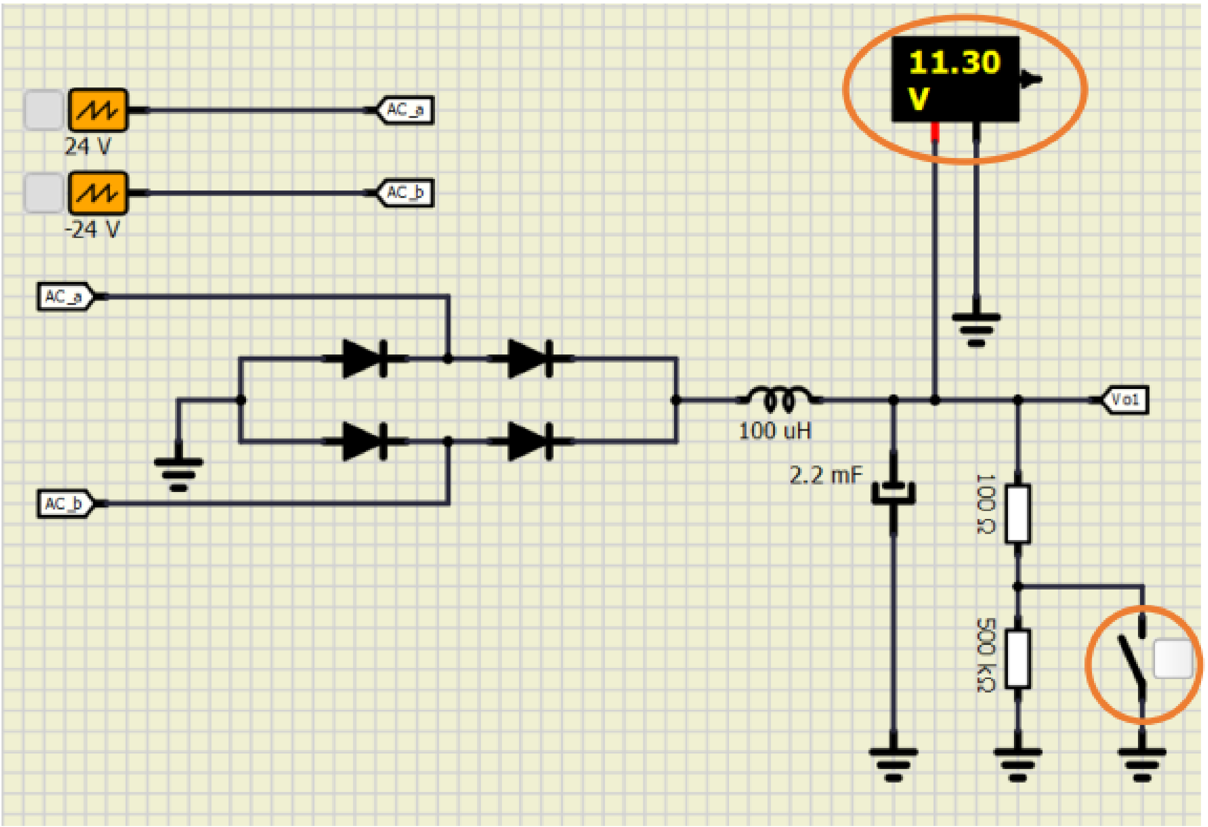




- Small R-L-C (large cutoff frequency)
  - Less smoothing with fast response (green curve)
- Large R-L-C (Small cutoff frequency)
  - More smoothing with slow response (yellow curve)

Effect of load change

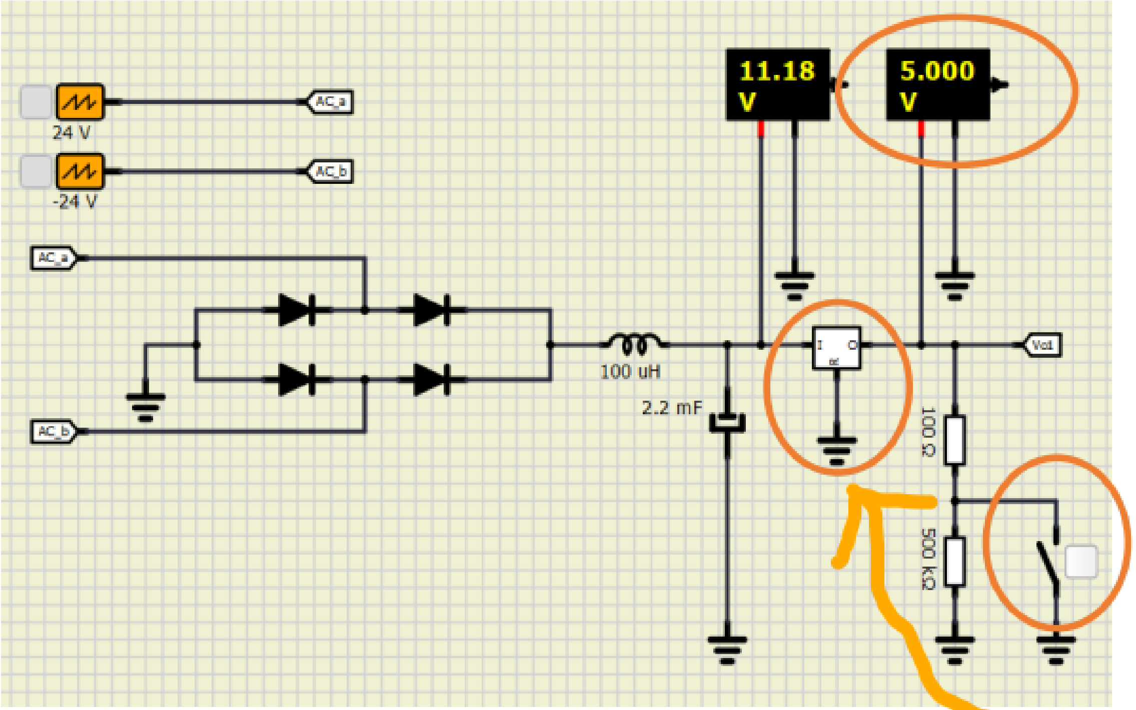


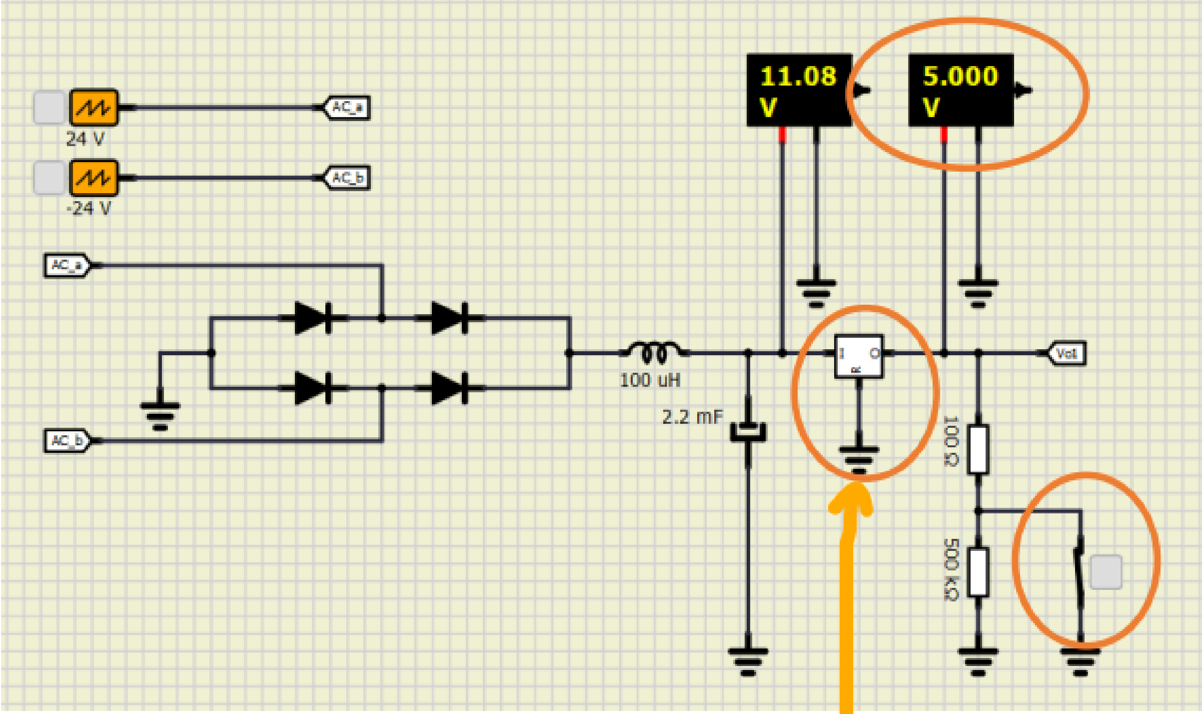


- A change on the output voltage with load change

Linear regulator

To solve the problem of loading effect





7805 VOLTAGE REGULATOR

but it has a disadvantage
that it becomes very hot , so it has small efficiency

Switched-mode power supply

it has high Efficiency

A switched-mode power (SMPS) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently.

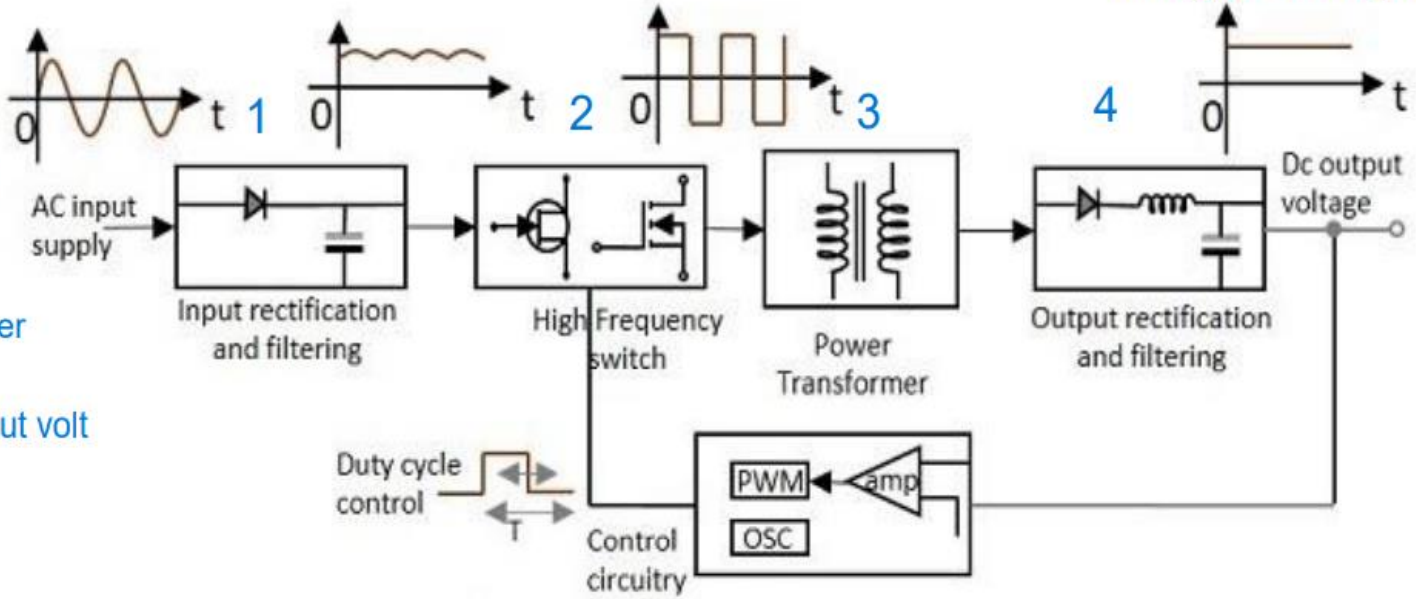
this DC value is a function of the Duty Cycle
if we change it we change the DC Output
that give us a great flexability

1- Rectifiring input signal

2 - enter it to High Frequency switch
to cut it and convert it to AC again

3- step down it by a power transformer

4 - Rectifiring it again to get DC output volt

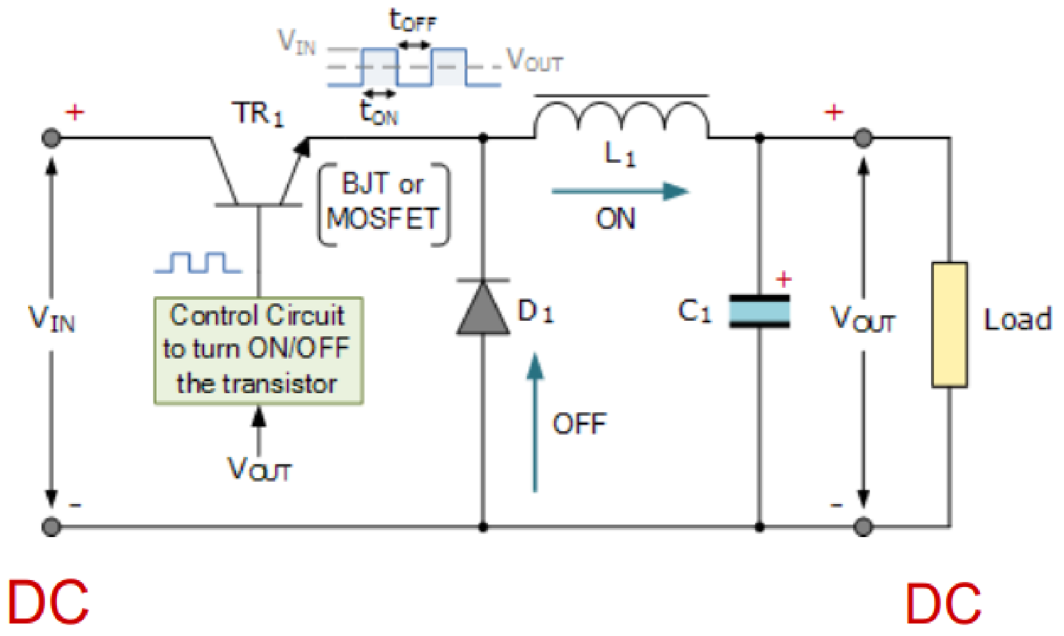


Functional block diagram of SMPS

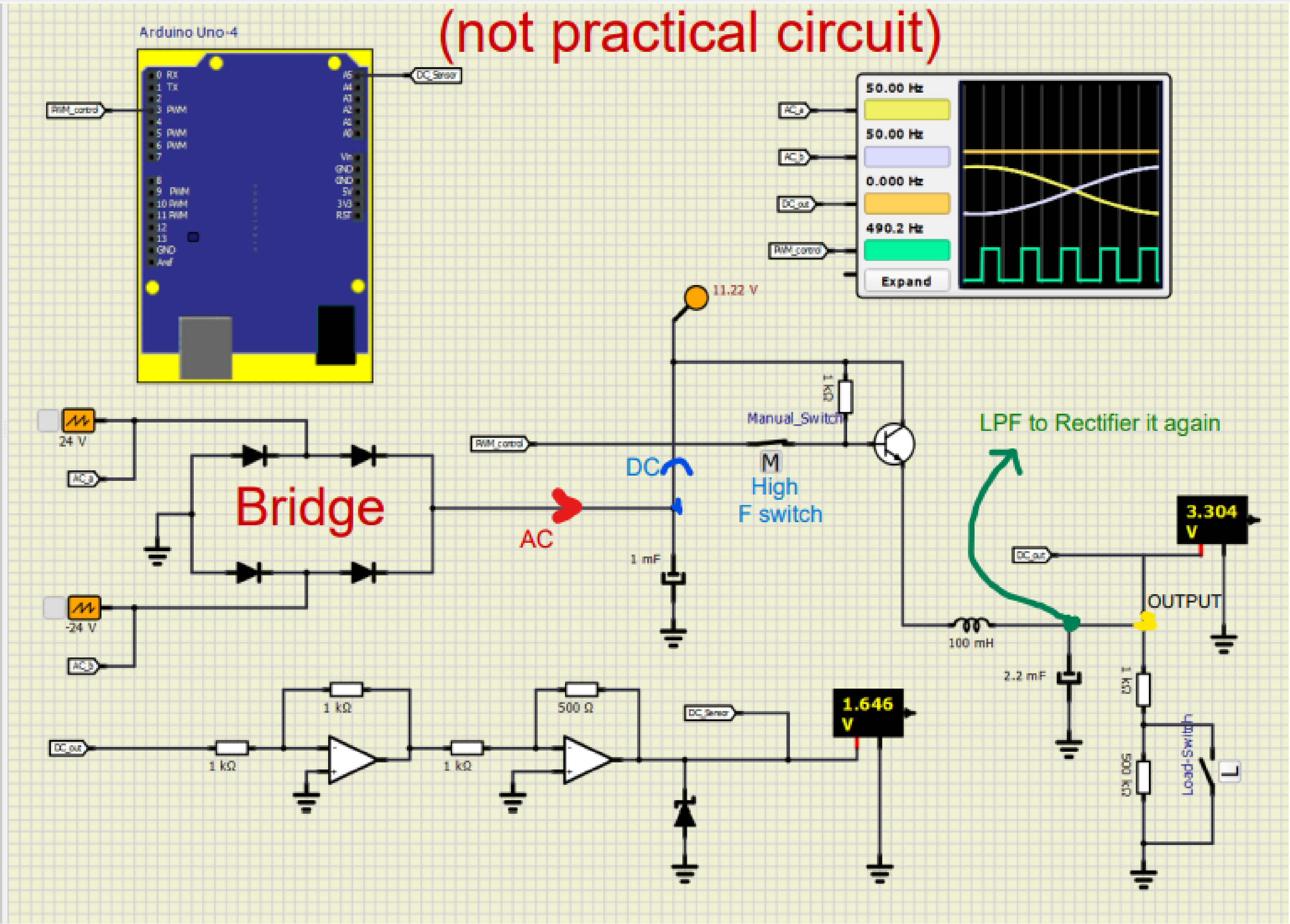
Switched-mode power supply

Buck converter

The Buck switching regulator is a type of switch mode power supply circuit that is designed to efficiently reduce DC voltage from a higher voltage to a lower one, that is it subtracts or “Bucks” the supply voltage, thereby reducing the voltage available at the output terminals without changing the polarity. In other words, the buck switching regulator is a step-down regulator circuit, so for example a buck converter can convert say, +12 volts to +5 volts.



Switched-mode power supply using Arduino (Concept Ct.) (Target 3.3 Volt)



Switched-mode power supply using Arduino (Concept Ct.) (Target 3.3 Volt)

(cont.)

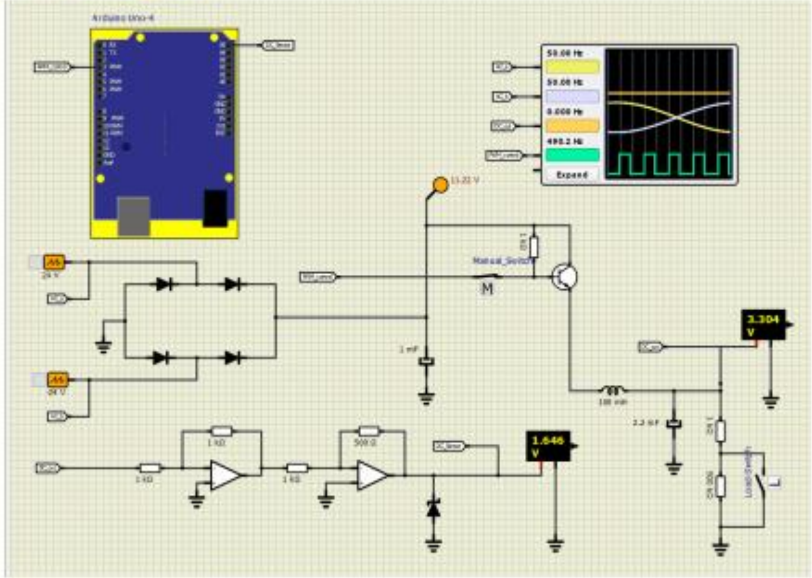
```
#define ANALOG_IN_PIN 5
#define ANALOG_OUT_PIN 3
#define MAX_VAL 1000
#define MAX_U MAX_VAL
#define MIN_U 0
#define MAX_IN_V 10.0

void setup() {   Serial.begin(9600);}
float read_val(void){
    int val = analogRead(ANALOG_IN_PIN);
    float ret=MAX_VAL*(val/1023.0);
    return (ret);
}
void set_val(float f_v){
    int i_v=(long int)((f_v/MAX_VAL)*254);
    i_v=(i_v<=0)?1:i_v;
    i_v=(i_v>254)?254:i_v;
    analogWrite(ANALOG_OUT_PIN,i_v);
}

float r=3.3*MAX_VAL/MAX_IN_V;
float ui,up,ud,e,u;
float e_old,ui_old;

//float Kp=0.005; float Ki=0.01; float Kd=0 ; Slow
float Kp=0.01; float Ki=0.1; float Kd=0 ; // Fast

void loop(void) {
    float v=read_val();
    e=r-v;
    up=Kp*e;
    ui=ui+Ki*e;
    ud=Kd*(e-e_old);
    u=up+ui+ud;
    if ( (u>MAX_U) || (u<MIN_U) ) {
        ui=ui_old;
        u=up+ui+ud;
    }
    e_old=e;
    ui_old=ui;
    Serial.print("r= ");    Serial.print(r);
    Serial.print(", v= "); Serial.print(v);
    Serial.print(", u= "); Serial.print(u);
    Serial.print(", e= "); Serial.println(e);
    set_val(u);
}
```



pwm compensates load effect to adjust volt at 3.3 v

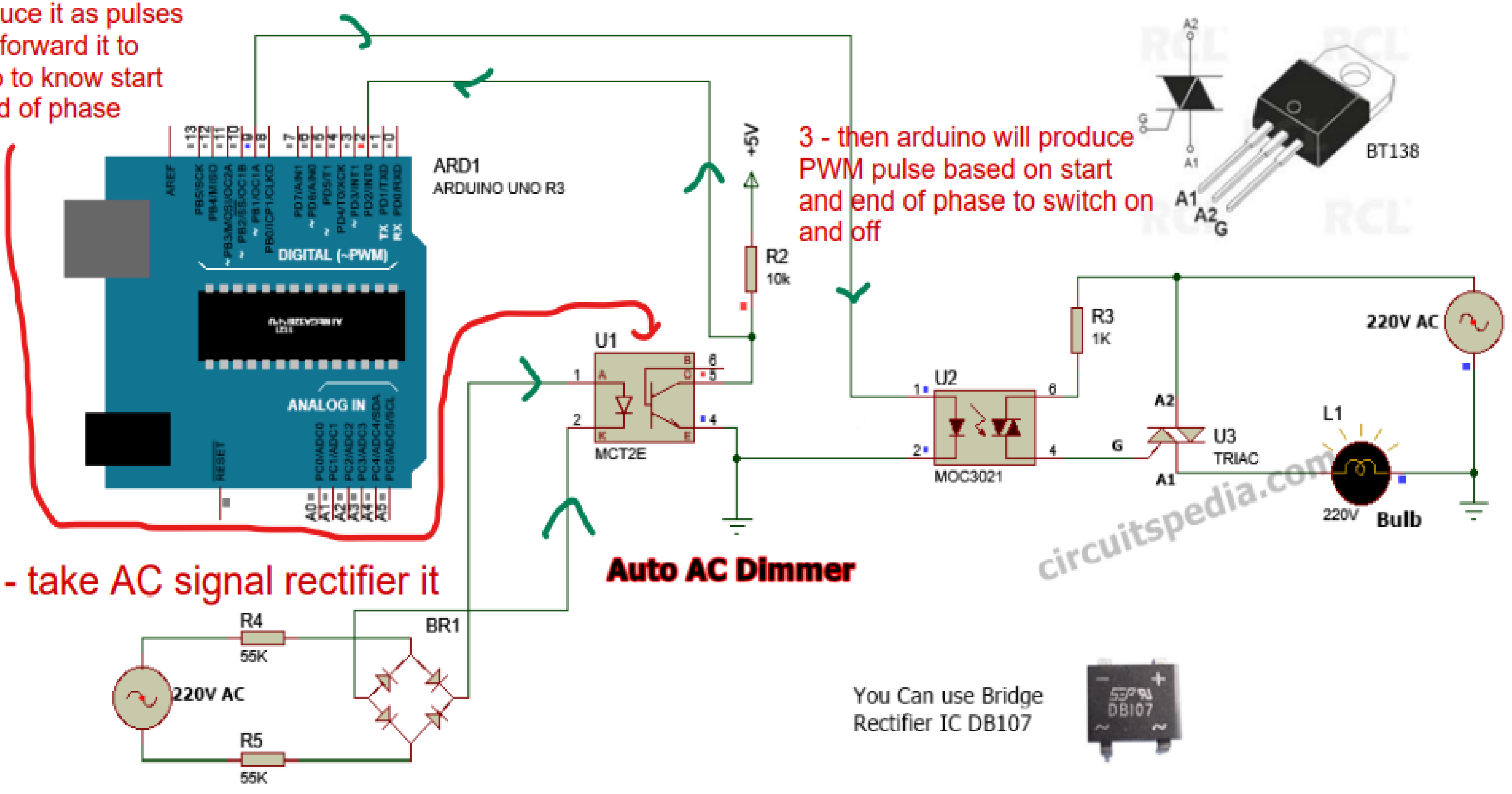
	Linear Regulator	Switch Mode Power Supply
Advantages	**Simple application:** can be implemented as an entire package and added to a circuit with only two additional filter capacitors. **Low cost:** If your device requires a power output of less than 10W. **Low noise/ripple:** have a very low output voltage ripple and high bandwidth. This makes them ideal for any noise-sensitive applications including communication and radio devices.	**Small form factor:** it operates at a high frequency reduces its volume and weight ,This allows a switching power supply to enjoy a much smaller form factor than linear regulators **High efficiency:** it's made without dissipating excessive amounts of heat. efficiency can be as high as 85%-90% **Flexible applications:** Additional windings can be added to a switching power supply to provide more than one output voltage.
Disadvantages	**Limited flexibility:** can only be used to step down voltage, For an AC-DC power supply, a transformer with rectification and filtering will need to be placed before the linear power supply which will add to overall costs and effort. **Limited outputs:** Linear regulated power supplies only provide one output voltage. **Poor efficiency:** The average linear regulated device achieves an efficiency between 30%-60% due to heat dissipation.	**Complicated design.** Compared to linear regulators, planning and designing a switching power supply is typically reserved for power specialists. **High-frequency noise:** The switching operation of the MOSFET within a switching power supply provides high-frequency noise in the output voltage. This often requires the use of RF shielding and EMI filters in noise-sensitive devices. **Higher cost:** For lower power outputs of 10W or less, it's cheaper to use a linear regulated power supply.

AC Dimmer

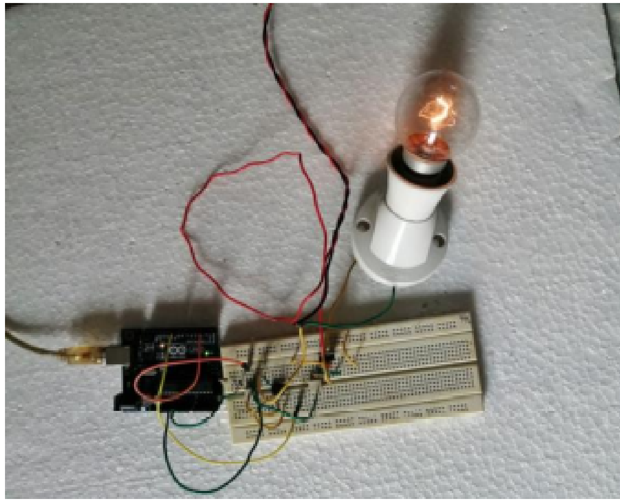
2- produce it as pulses of(0,1) forward it to arduino to know start and end of phase

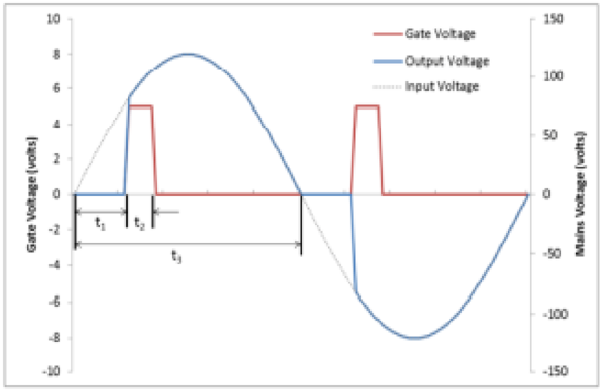
3 - then arduino will produce PWM pulse based on start and end of phase to switch on and off

1- take AC signal rectifier it

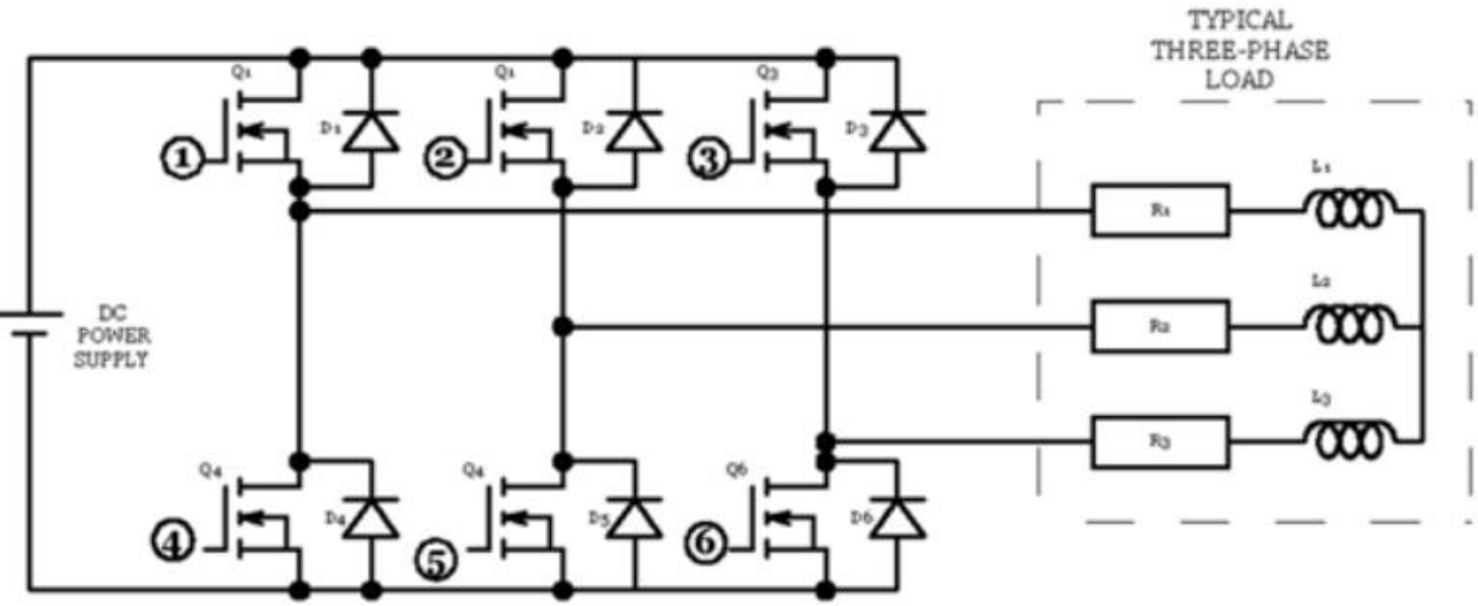


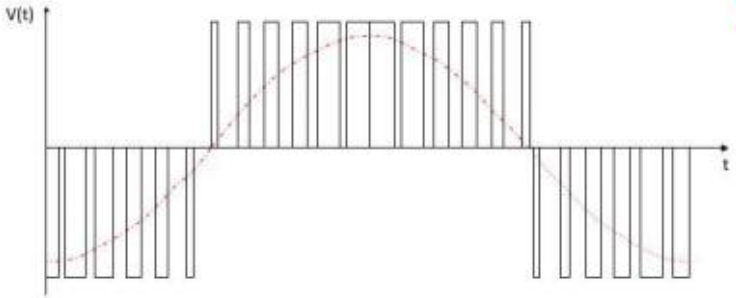
You Can use Bridge Rectifier IC DB107



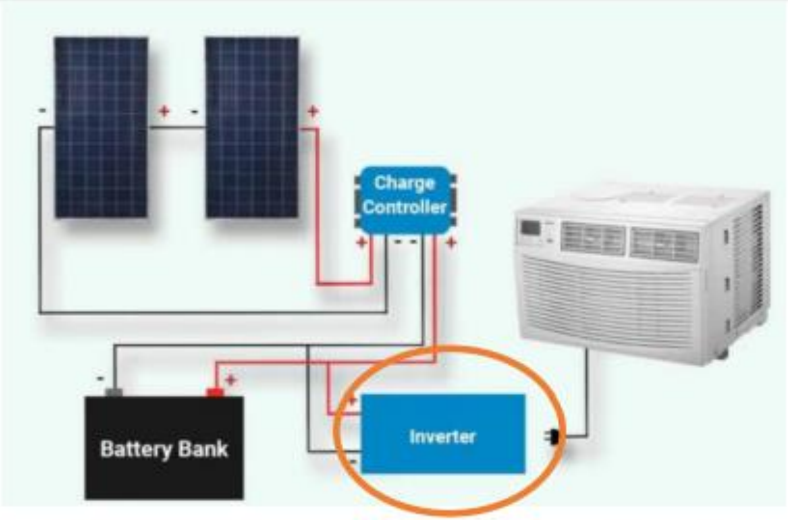


Variable-frequency drive VFD
(AC Inverter)

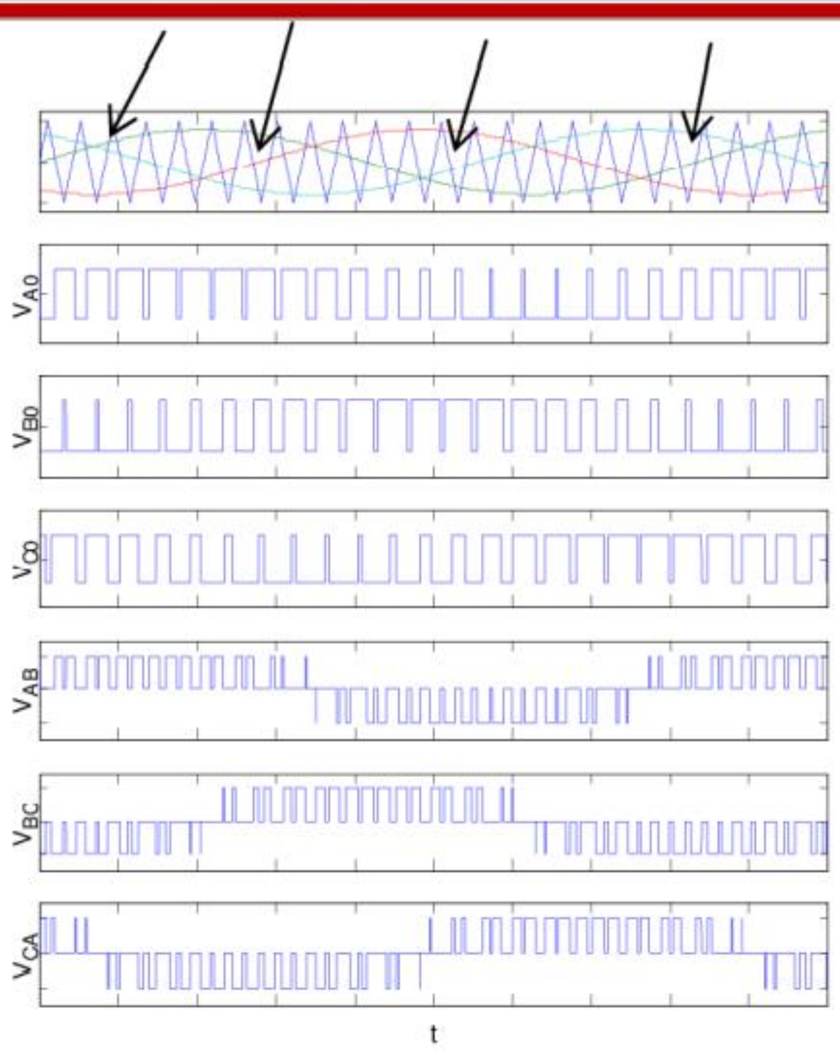




Convert from DC to 3 phase AC



Variable-frequency drive VFD
(AC Inverter) (Cont.)



PWM signals
out of phases as we like