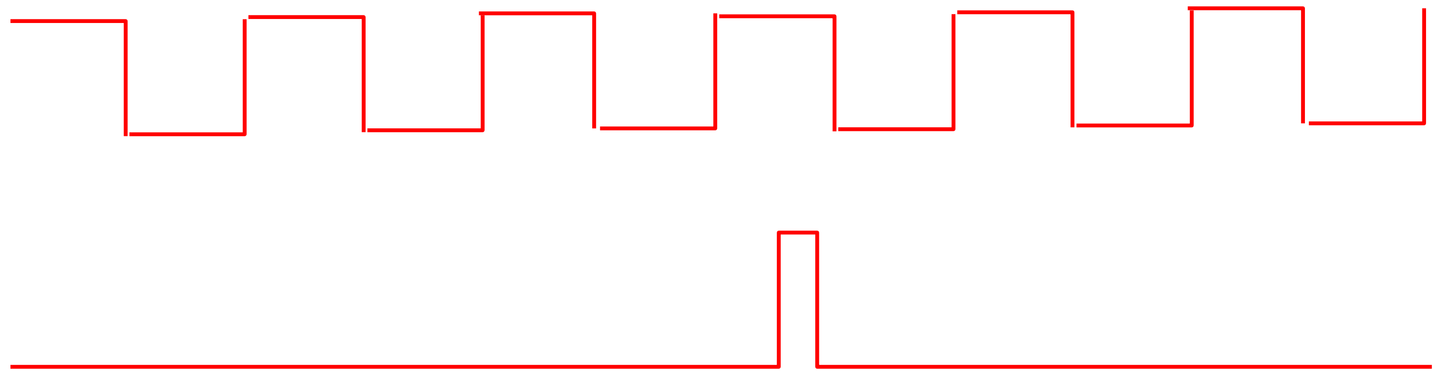
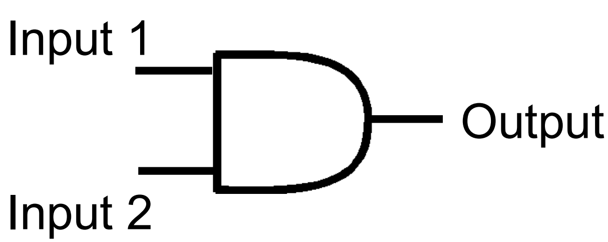
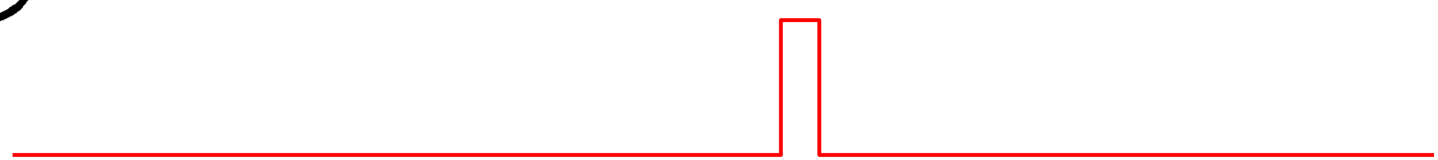
Lab 12: Timing and Control

Digital Timing: True or False; 1 or 0

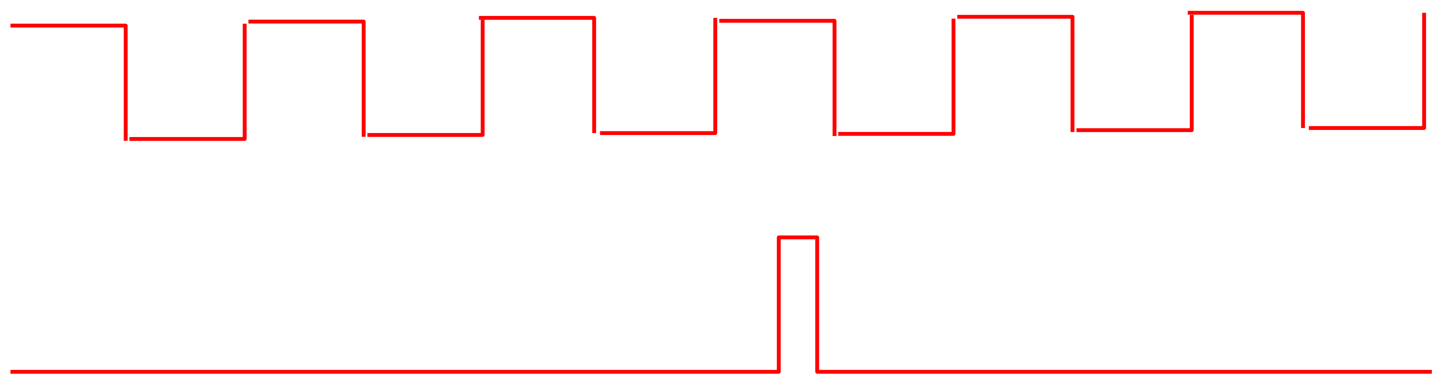


AND Gate

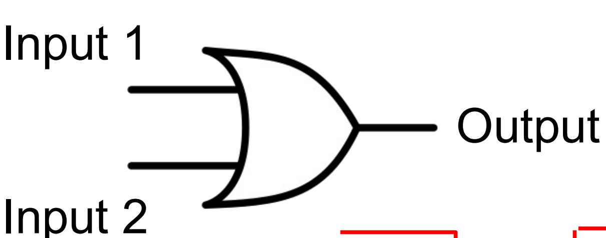


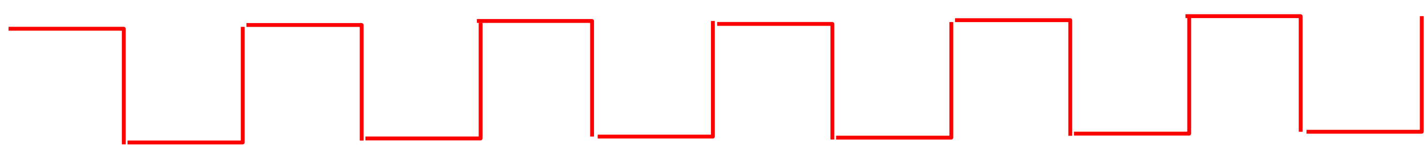


Digital Timing: True or False; 1 or 0

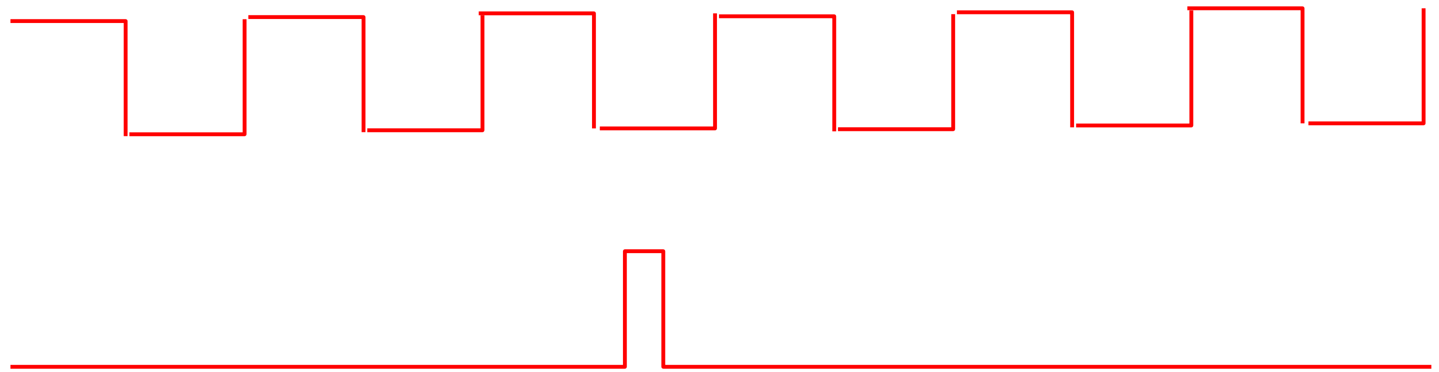


OR Gate

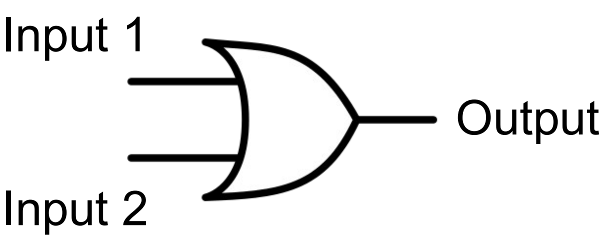


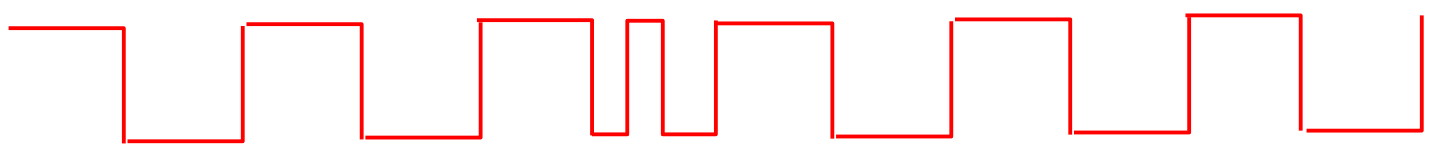


Digital Timing: True or False; 1 or 0

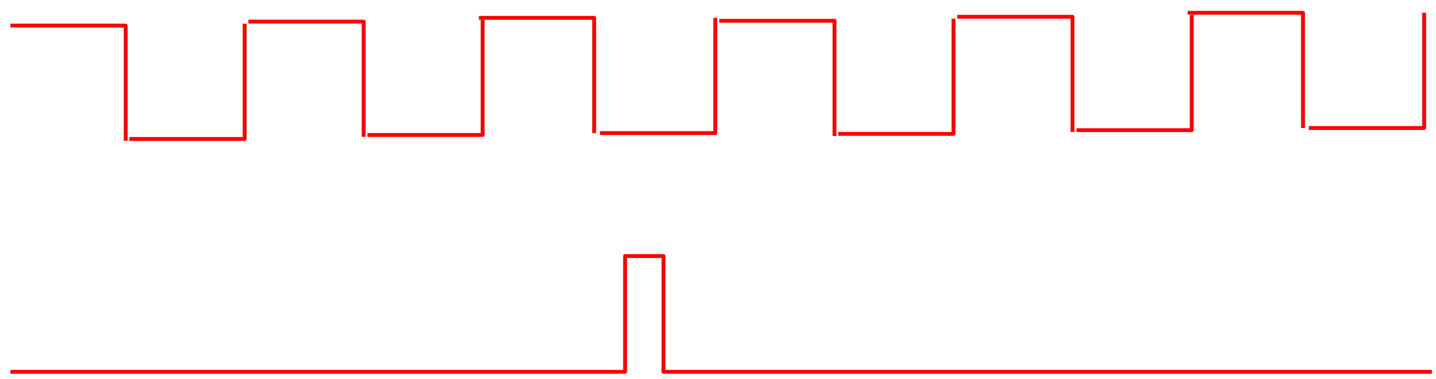


OR Gate

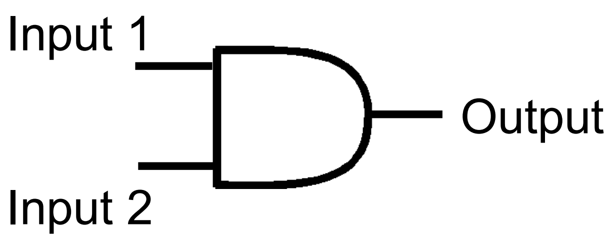




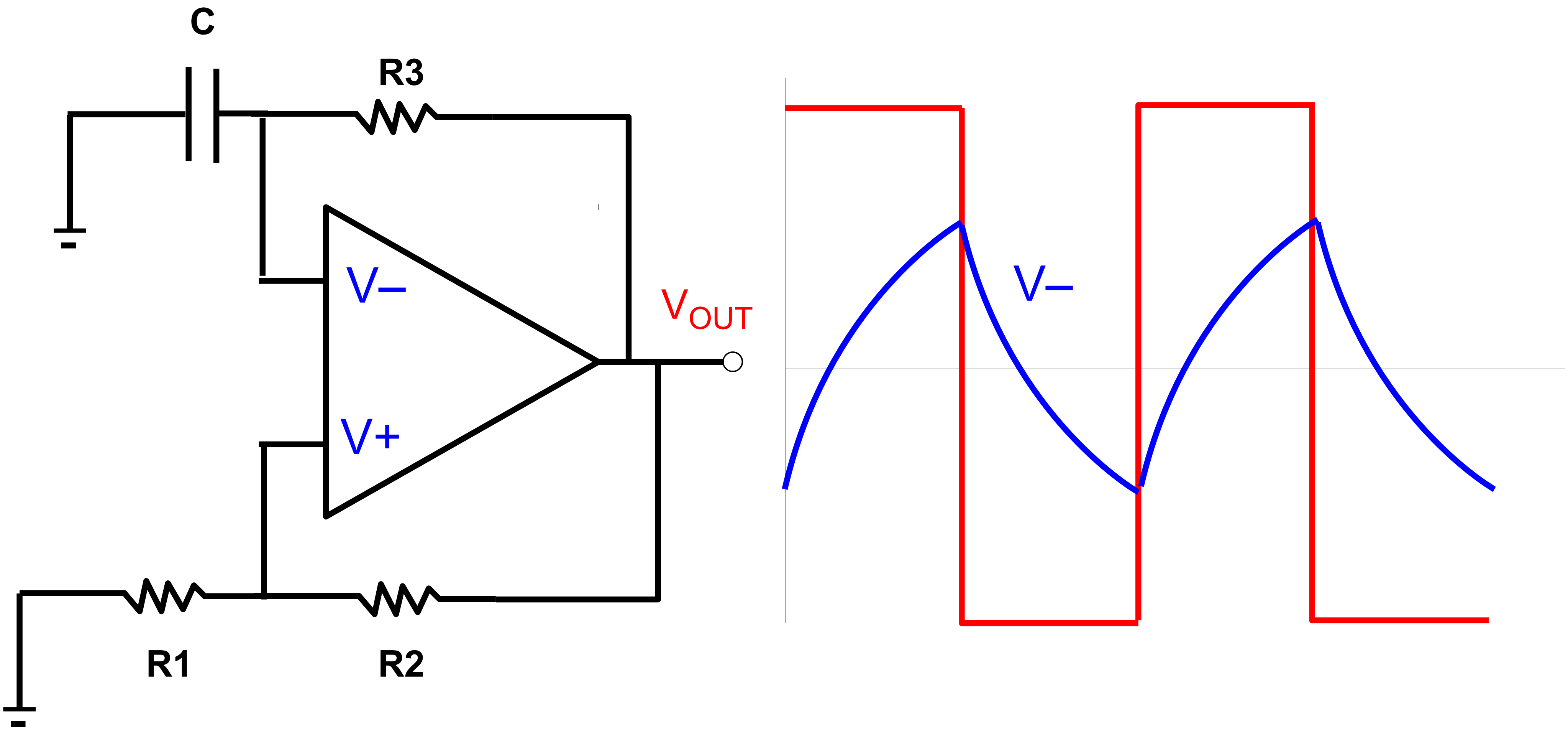
Digital Timing: True or False; 1 or 0



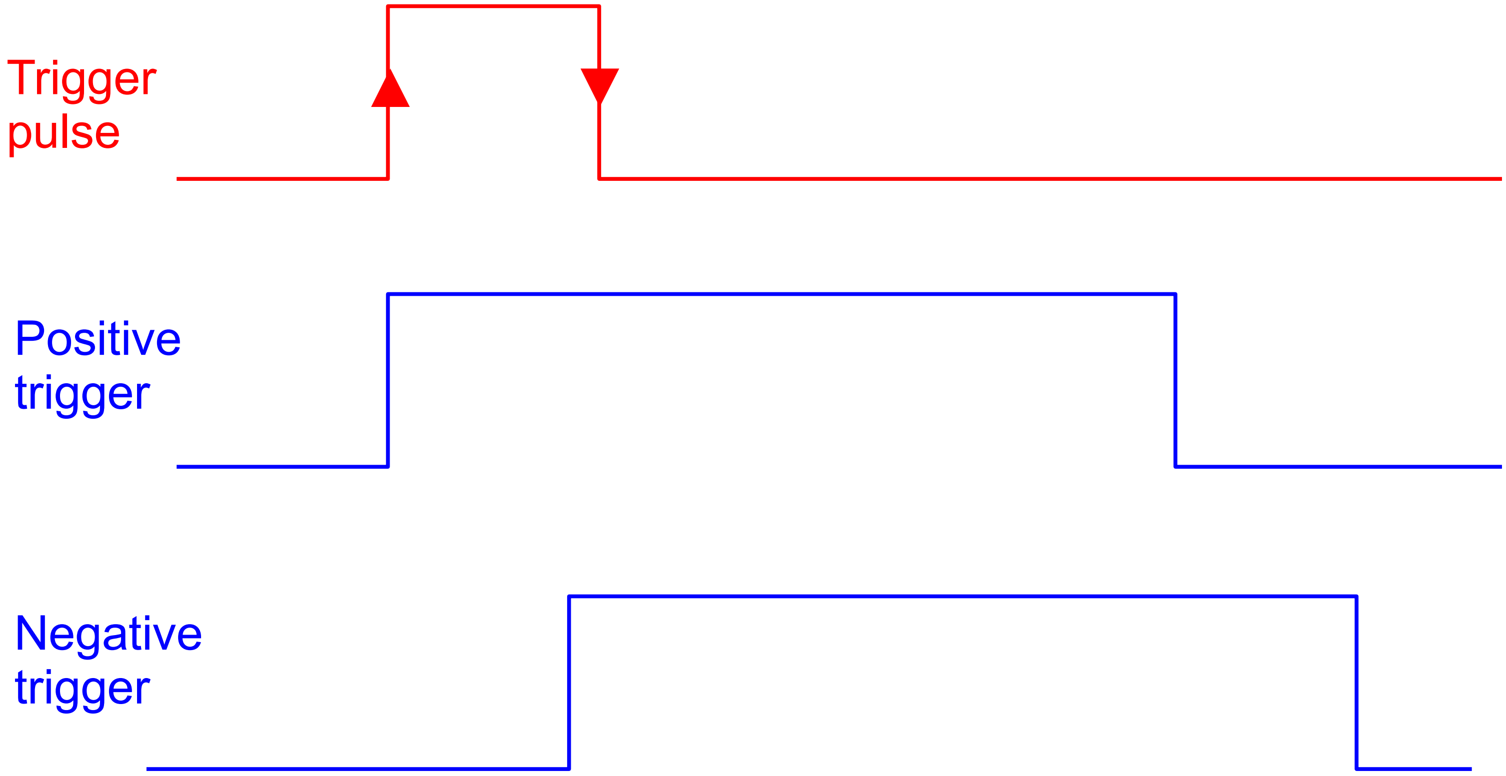
AND Gate



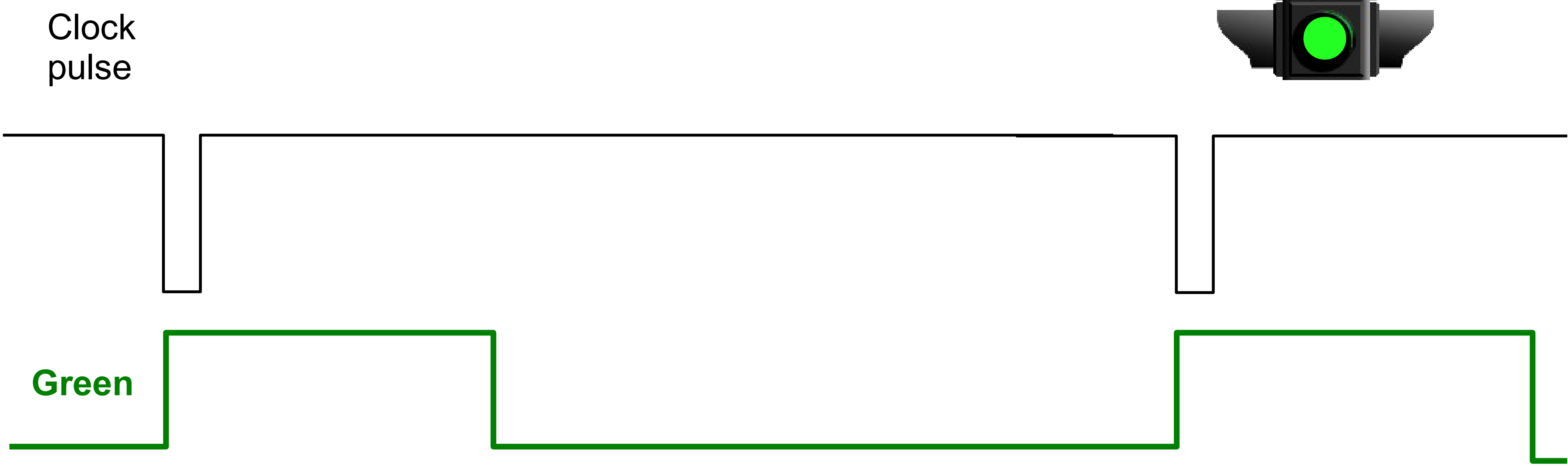
Relaxation Oscillator



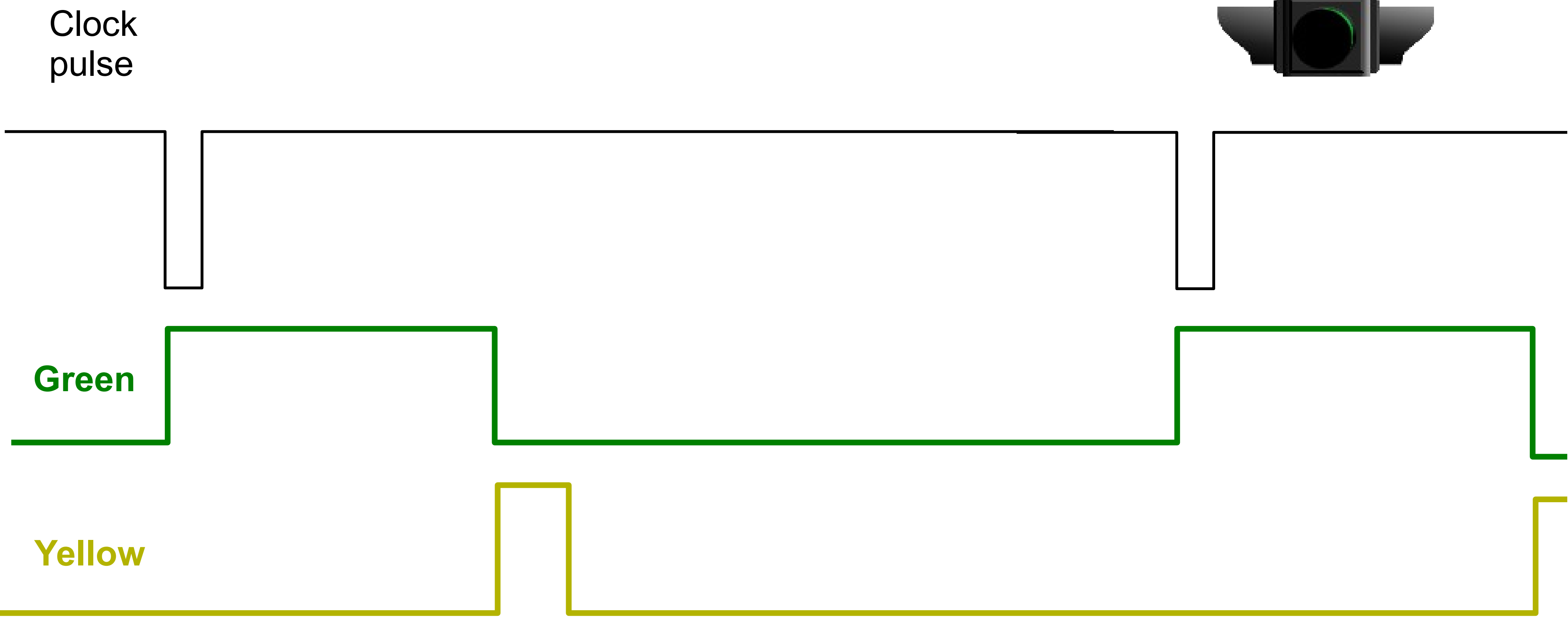
Edge triggering of single-shot square pulse



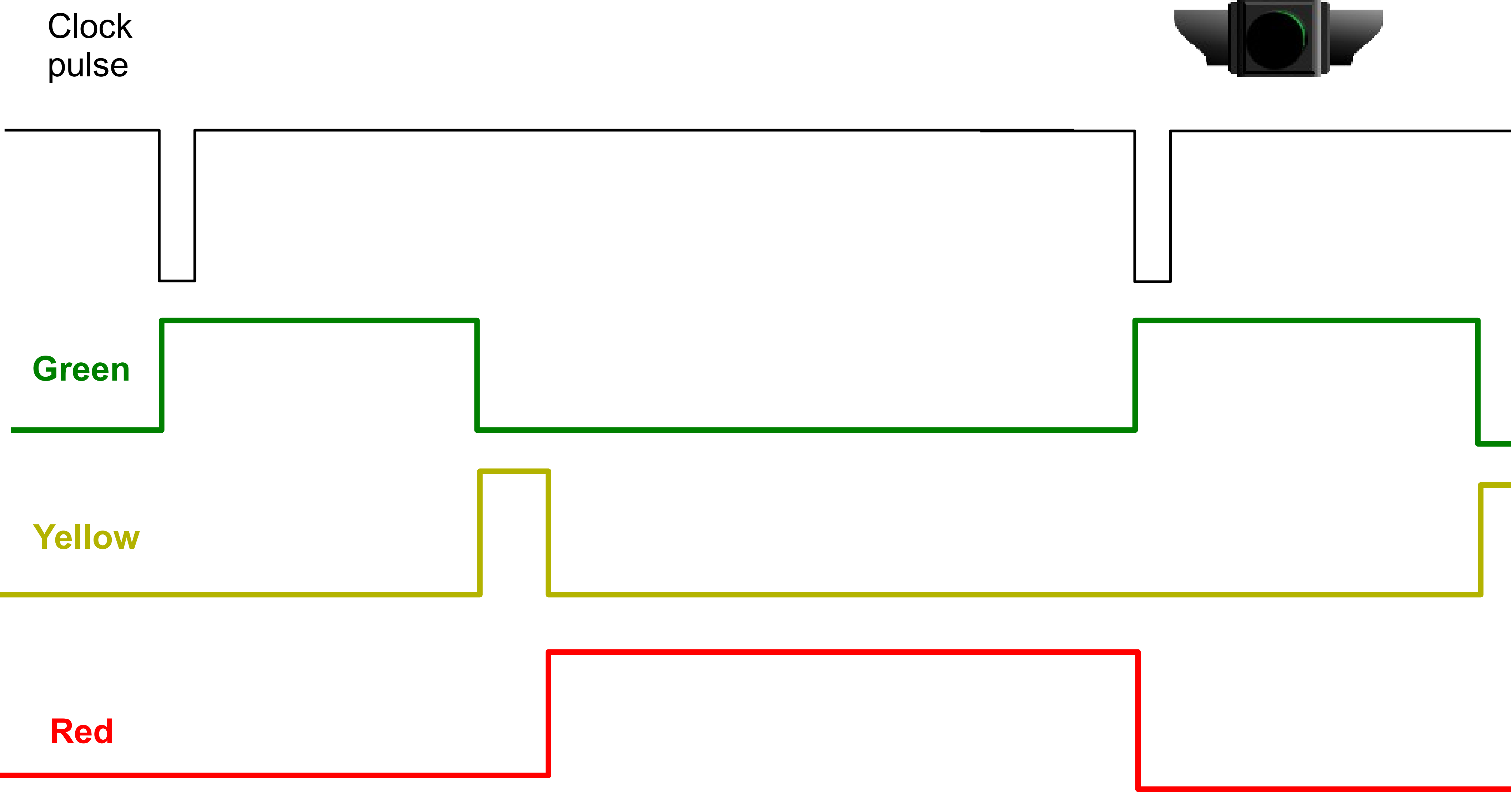
Timing diagram: Traffic Light



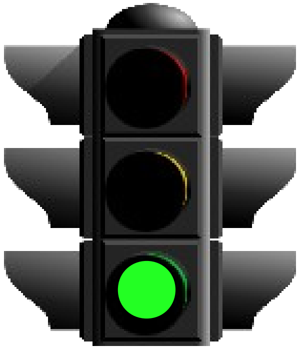
Timing diagram: Traffic Light



Timing diagram: Traffic Light



Timing: Traffic Light (State 1)



North-South bound

East-West bound

Timing: Traffic Light (State 2)

North-South bound

East-West bound

Timing: Traffic Light (State 3)

North-South bound

East-West bound

Timing: Traffic Light (State 4)

North-South bound

East-West bound

Timing: Traffic Light (State 5)

North-South bound

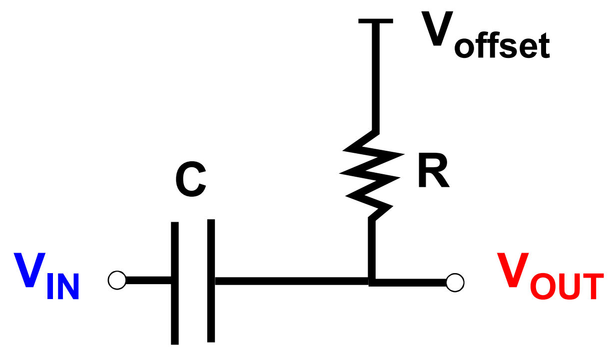
East-West bound

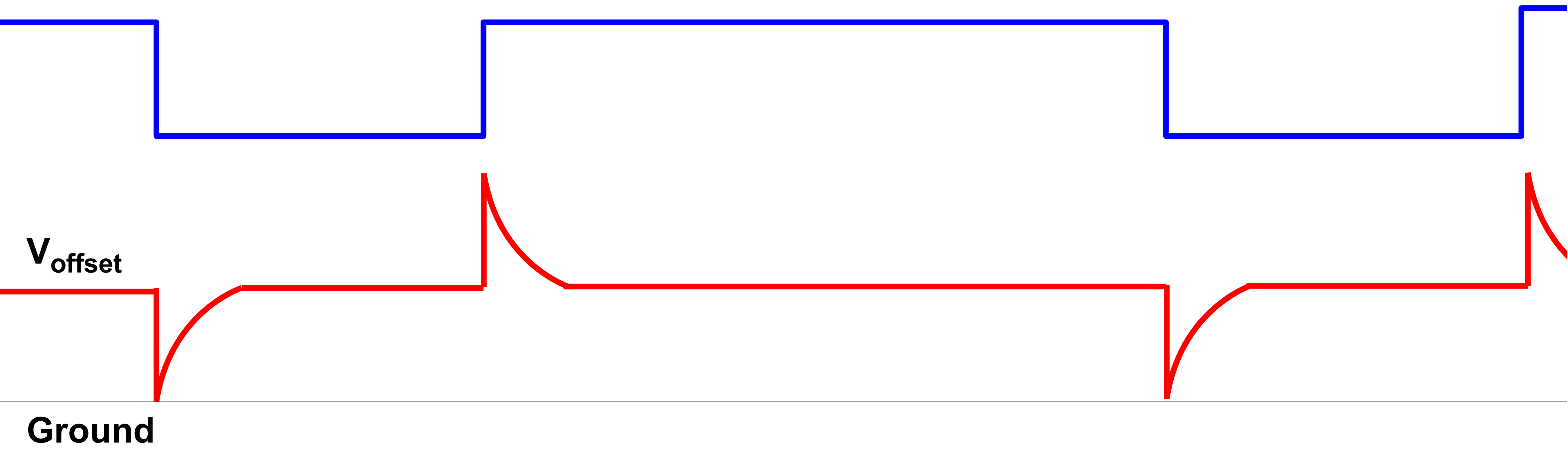
Timing: Traffic Light (State 6)

North-South bound

East-West bound

Differentiating pulses with RC circuit





100% Hardware	LabView + Hardware
Cheaper No PC No proprietary software/OS	Easier to setup/troubleshoot
More reliable No PC to crash	Easier to expand/adapt new versions
More compact Depends on complexity	LabView code more transparent than circuit schematic
Inherently faster Interface I/O limits speed	Probably better approach for research lab environment
Less power	

EMBEDDED SYSTEMS

Dedicated computer hardware replaces the general purpose PC

Inexpensive, low-power micro-controllers (RAM, Flash, I/O, etc)

Optimized to solve a specific problem or task

Examples

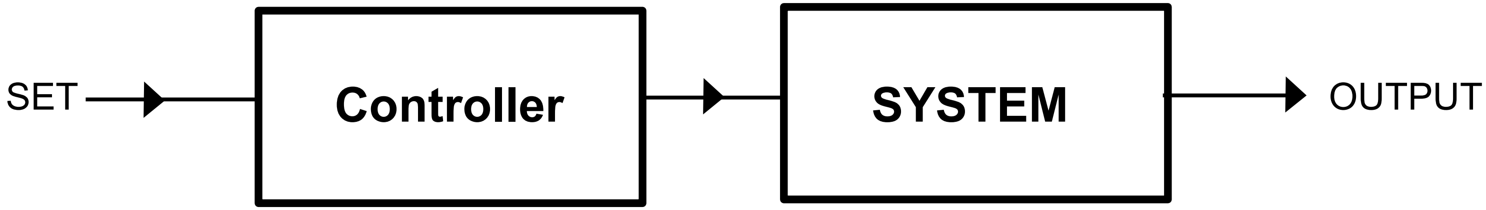
- Digital watch
- MP3 player
- Smoke detector
- Game console
- PDA
- Digital camera
- Cellphone
- GPS
- Microwave oven

Two-direction traffic light implemented with state-machine on a $1 TI micro-controller. Battery powered.

```
//Runs a 6 LEDS in sequence, simulating a two-direction traffic light.
//Implemented with timer interrupts using the 12 kHz VLO clock.
//MCU spends most of its time in LPM3.
//This is a state-machine with 6 states

#include <msp430g2253.h>
#ifndef TIMER0_A1_VECTOR
#define TIMER0_A1_VECTOR    TIMERA1_VECTOR
#define TIMER0_A0_VECTOR    TIMERA0_VECTOR
#endif

int main(void) {
   WDTCTL = WDTPW | WDTHOLD;            // Stop watchdog timer
   P1DIR |= BIT0 + BIT4 + BIT6; // Direction 1: Red, yellow, green on P1.0, 1.4, & 1.6
   P1DIR |= BIT1 + BIT2 + BIT3; // Direction 2: Red, yellow, green on P1.1, 1.2, & 1.3
   P1OUT |= BIT0 + BIT1 + BIT2 + BIT3 + BIT4 + BIT6; //Turn all LEDs on
   BCSCTL3 |= LFXT1S_2;  //Set low frequency clock to the 12 kHz VLO
   //Divide the VLO (ACLK) as follows: DIVA_0,1,2,3 correspond to divide by 1,2,4,8
   //For DCO = 150 kHz, set RSELx = 1 and DCOx = 3
   BCSCTL1 = DIVA_2;
   TACCR0=6000;  //12000 counts for 1 second at DIVA_0;
  //Maximum count is 65535 (unsigned 16-bit)
   TACCTL0 |= CCIE;  //Enable timer interrupt
   //Configure TACTL last because it starts the timer
   TACTL |= TASSEL_1 + MC_1;  //Set Timer A to ACLK; MC_1 to count up to TACCR0.
   _BIS_SR(GIE); //Enable global interrupts.  Shouldn't be set until module is fully configured
   LPM3;
   P1OUT &= ~(BIT0 + BIT1 + BIT2 + BIT3 + BIT4 + BIT6); //Turn off all LEDs
```

```
for (;;) {                    // Endless loop
    //State 1
        P1OUT &= ~BIT2; //Yellow 2 off
        P1OUT |= BIT0 + BIT1; //Both red LEDs on
        TACCR0=12000; //2 second wait
         LPM3;
    //State 2
        P1OUT &= ~BIT0; //Red 1 off
        P1OUT |= BIT6; //Green 1 on
        TACCR0=30000; //5 second wait
        LPM3;
    //State 3
        P1OUT &= ~BIT6; //Green 1 off
        P1OUT |= BIT4; //Yellow 1 on
        TACCR0=12000; //2 second wait
        LPM3;
    //State 4
        P1OUT &= ~BIT4; //Yellow 1 off
        P1OUT |= BIT0 + BIT1; //Both red LEDs on
        TACCR0=12000; //2 second wait
        LPM3;
    //State 5
        P1OUT &= ~BIT1; //Red 2 off
        P1OUT |= BIT3; //Green 2 on
        TACCR0=24000; //4 second wait
        LPM3;
    //State 6
        P1OUT &= ~BIT3; //Green 2 off
        P1OUT |= BIT2; //Yellow 2 on
        TACCR0=12000; //2 second wait
        LPM3;
          }
}

#pragma vector=TIMER0_A0_VECTOR
 __interrupt void timerfoo (void)
{
        LPM3_EXIT;
 }
```

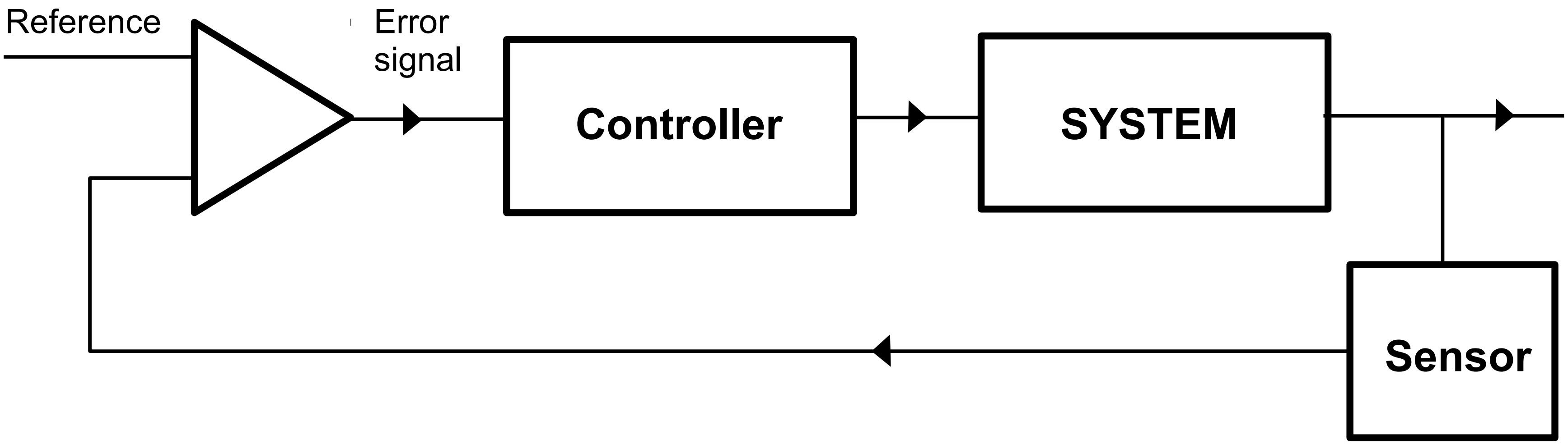
CONTROL: OPEN LOOP



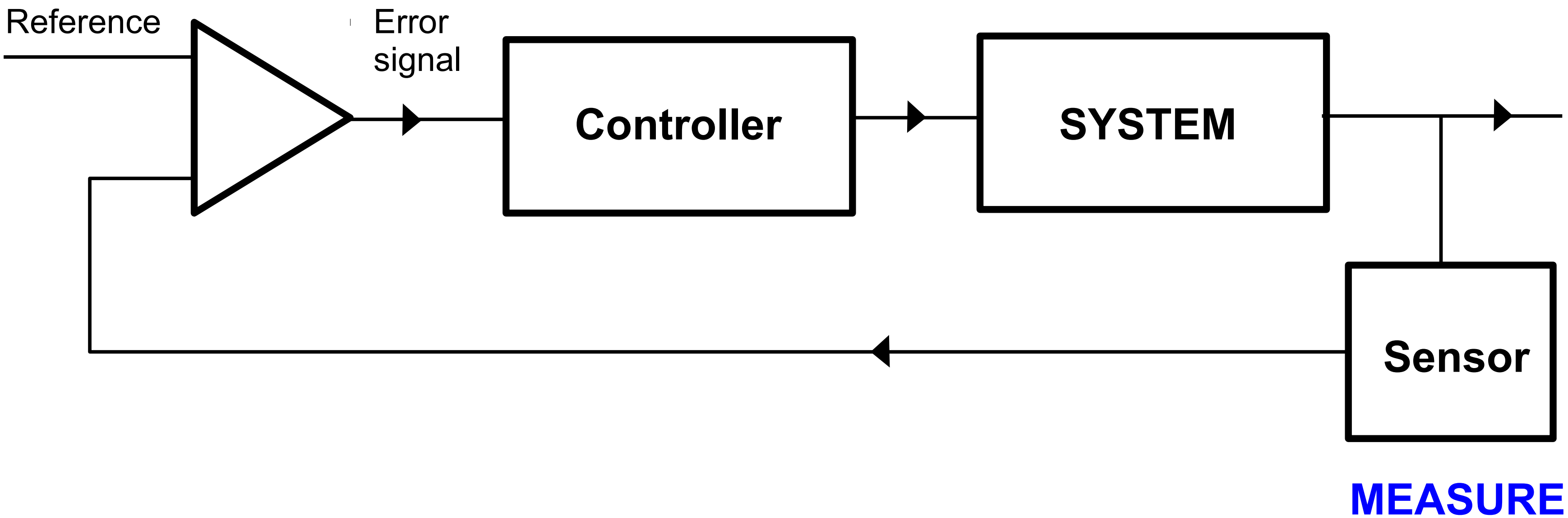
EXAMPLES:

- Washing machine
- Lawn sprinkler system

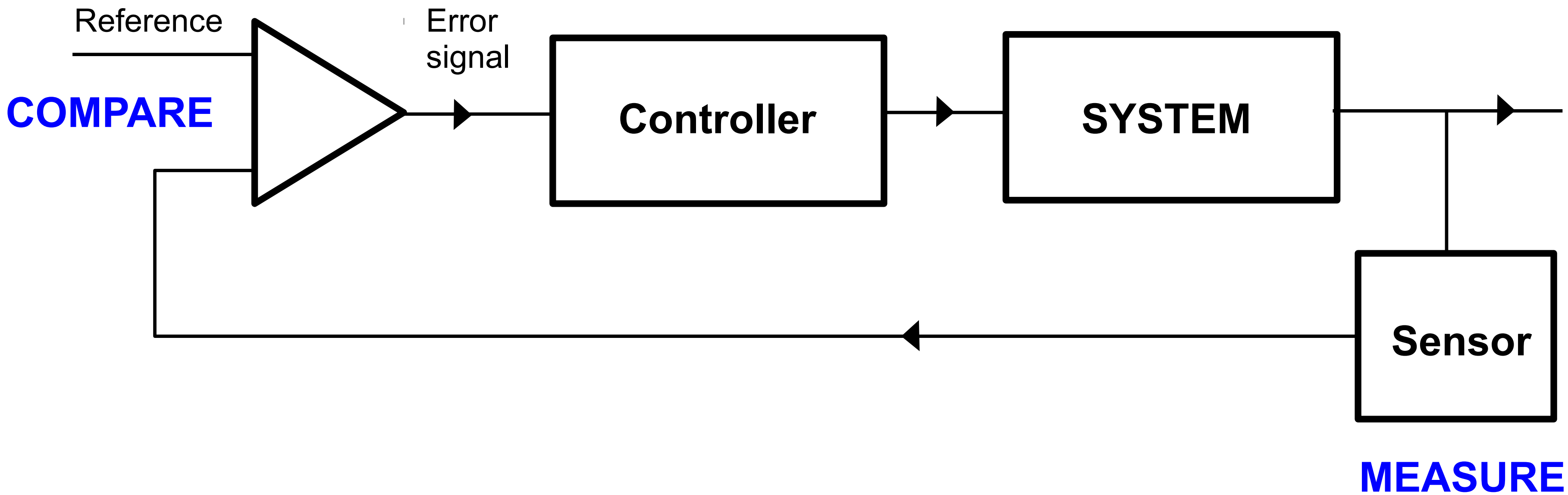
CONTROL: CLOSED LOOP



CLOSED LOOP

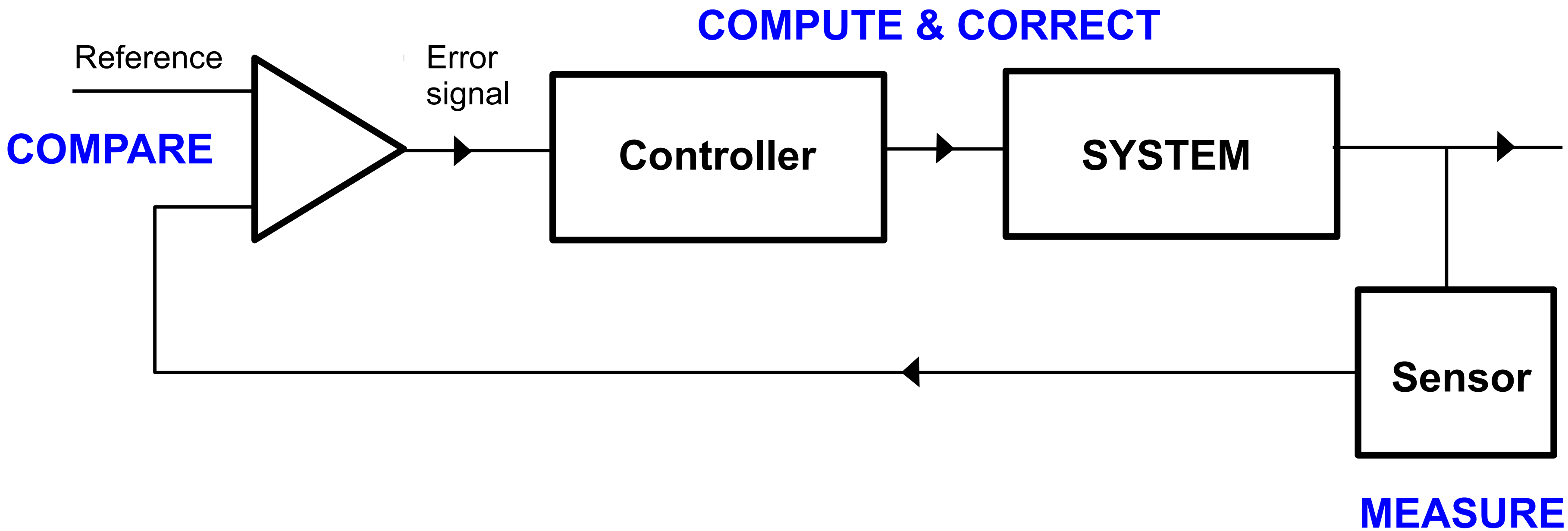


CLOSED LOOP



Reference
Error
signal
COMPARE
Controller
SYSTEM
Sensor
MEASURE

CLOSED LOOP



COMPUTE & CORRECT
Reference
Error
signal
COMPARE
Controller
SYSTEM
Sensor
MEASURE

Examples of closed loop controllers

Cruise control on car

Thermostat on furnace

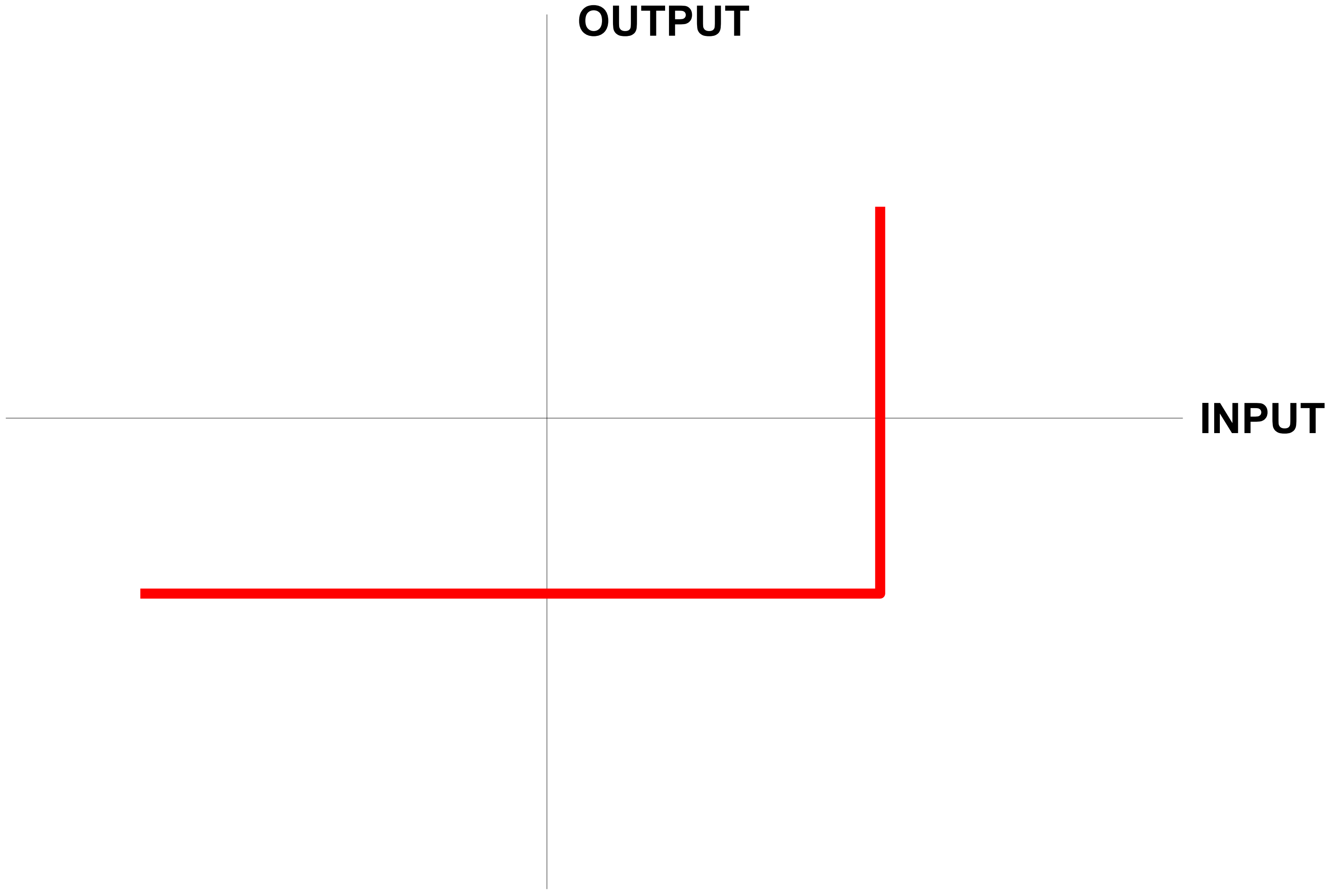
Water level in hot water heater or swamp cooler

Compact disk player

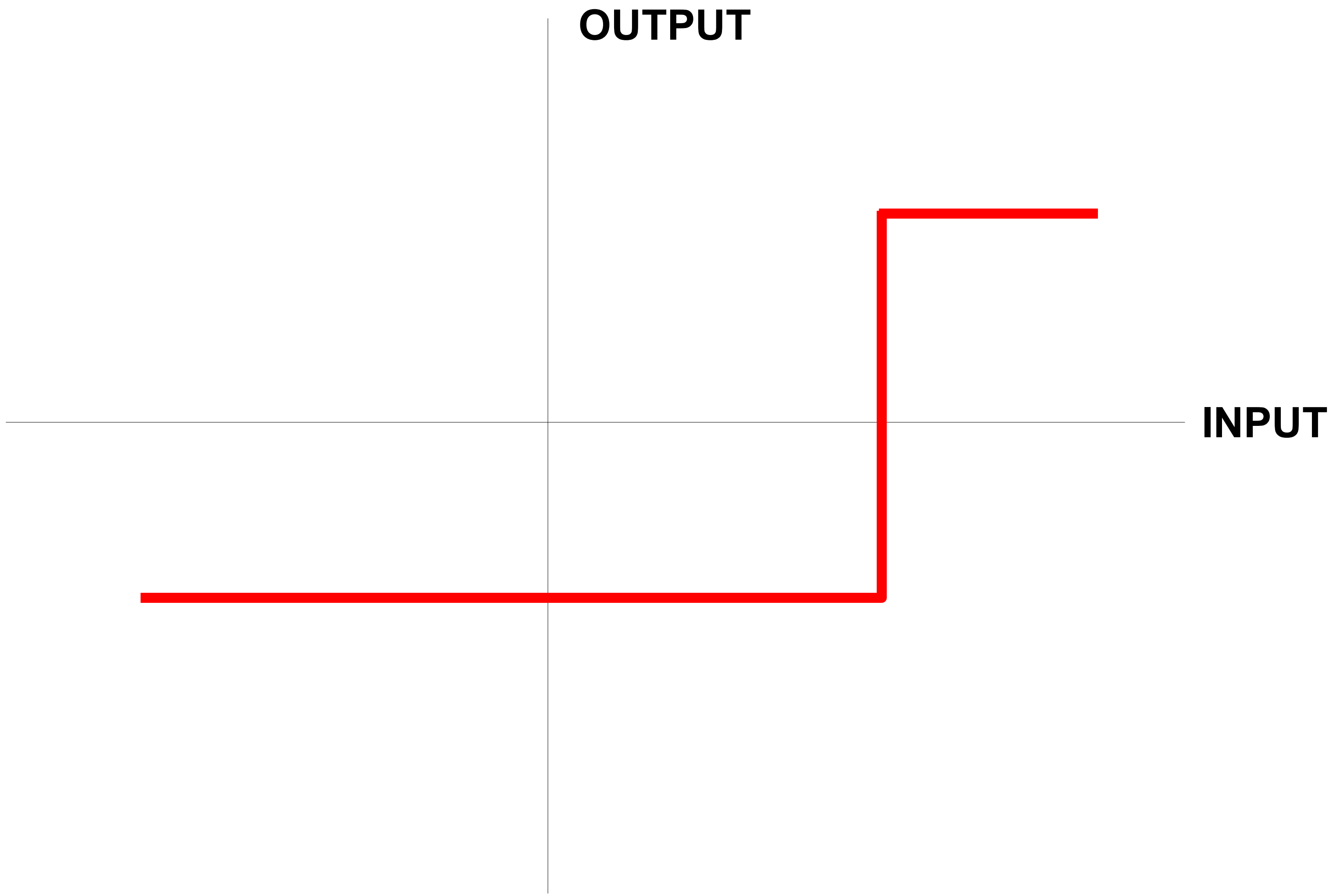
Cabin air pressure in passenger plane

Clock on a PC

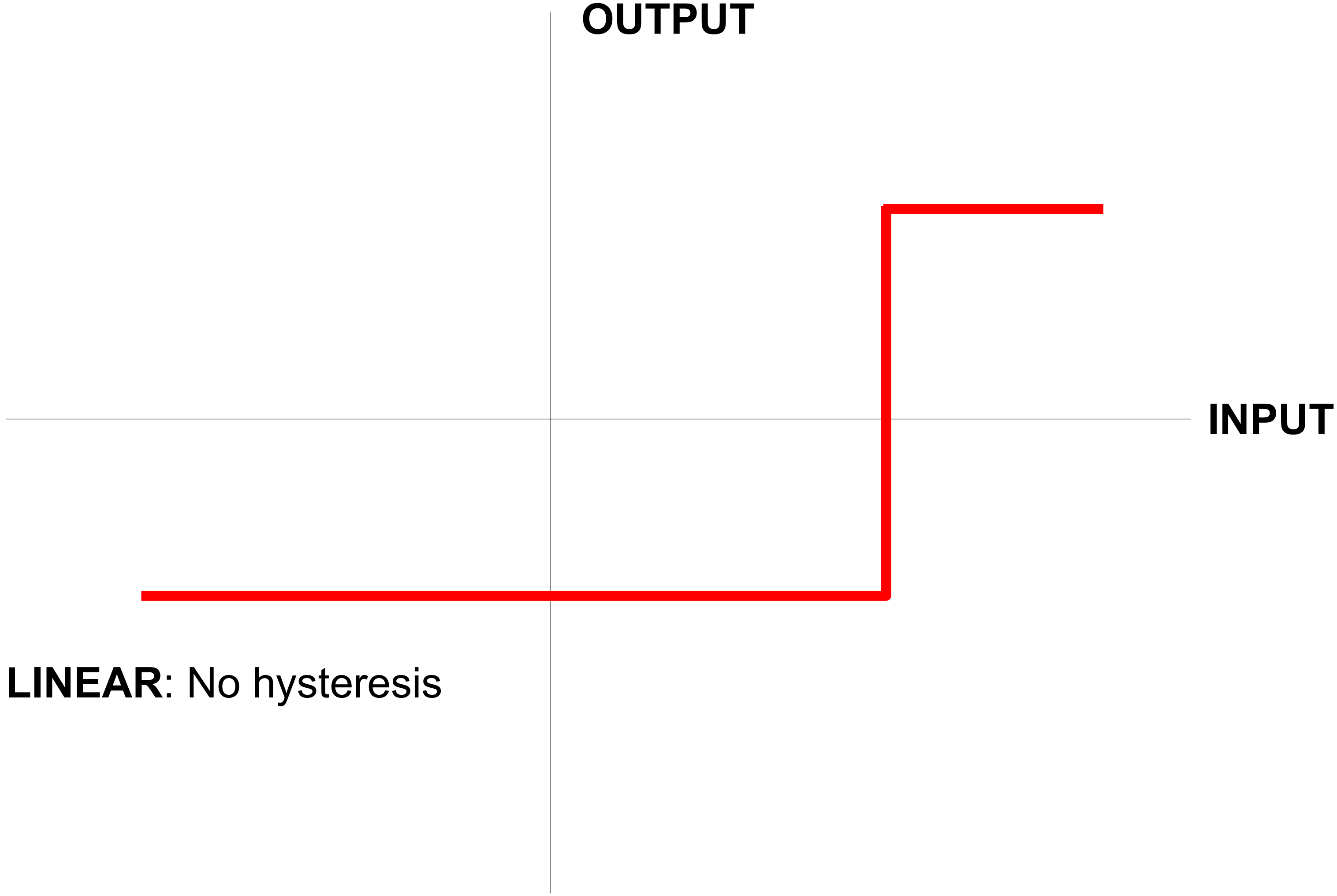
HYSTERETIC CLOSED LOOP CONTROLLER



HYSTERETIC CLOSED LOOP CONTROLLER

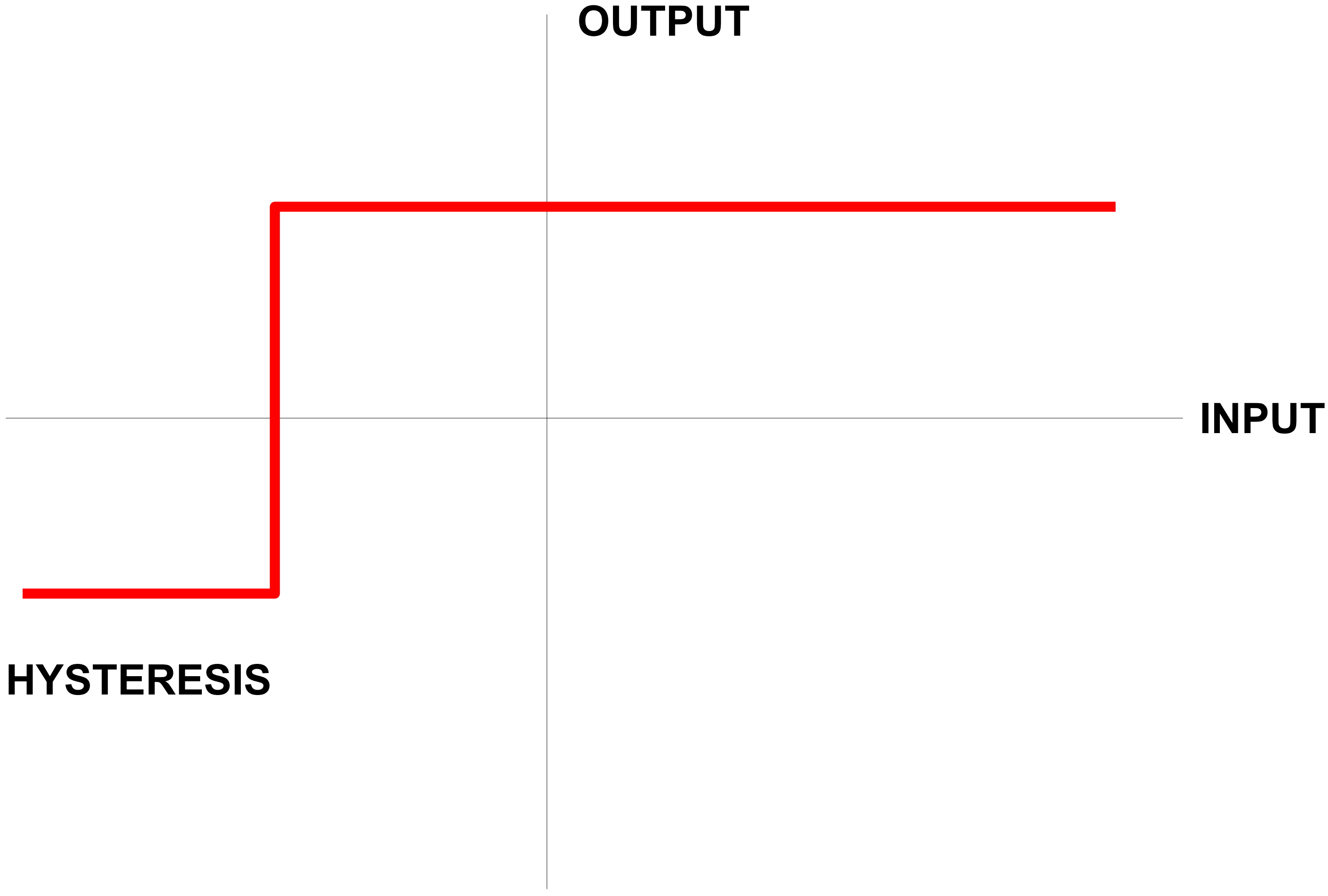


HYSTERETIC CLOSED LOOP CONTROLLER

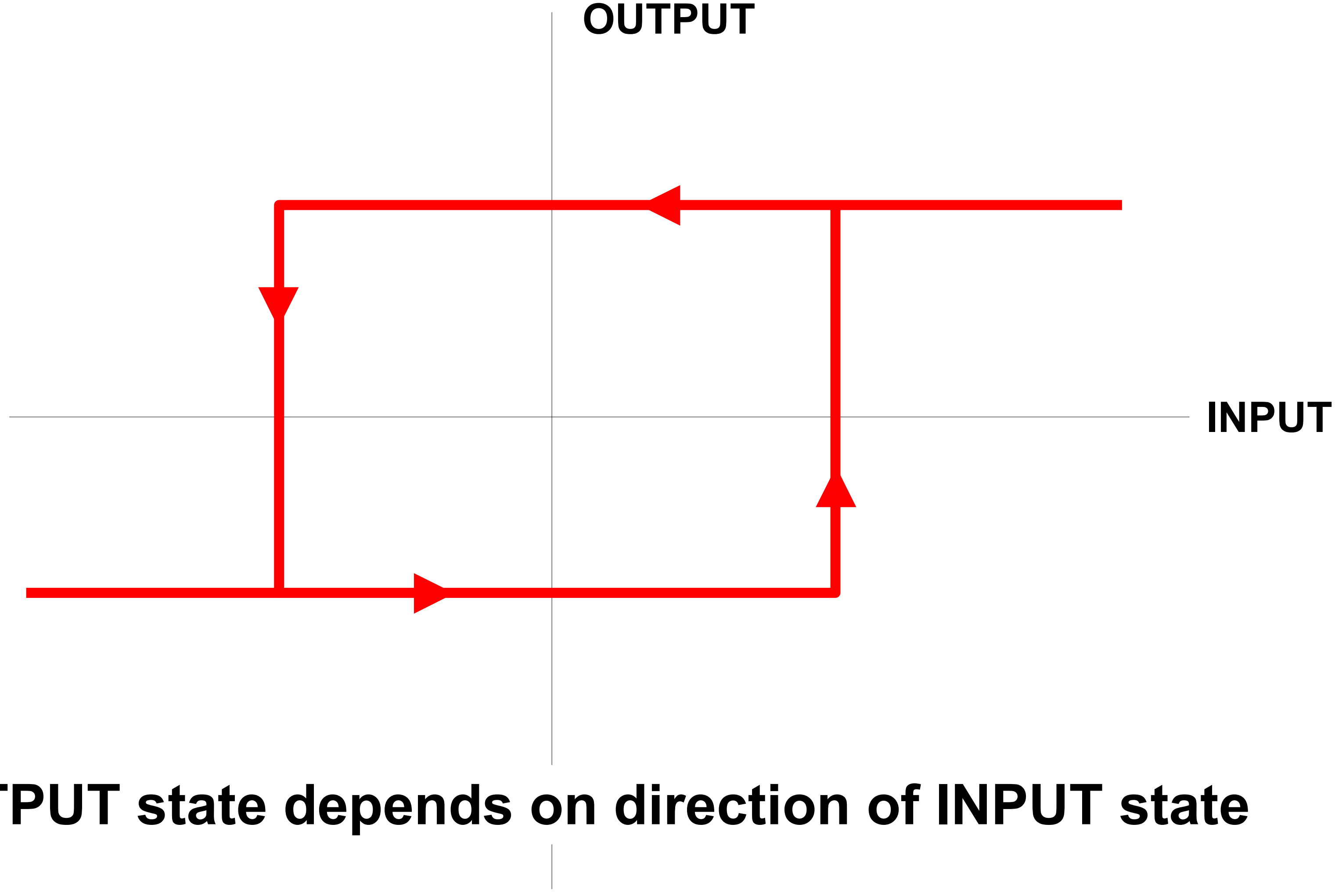


LINEAR: No hysteresis

HYSTERETIC CLOSED LOOP CONTROLLER

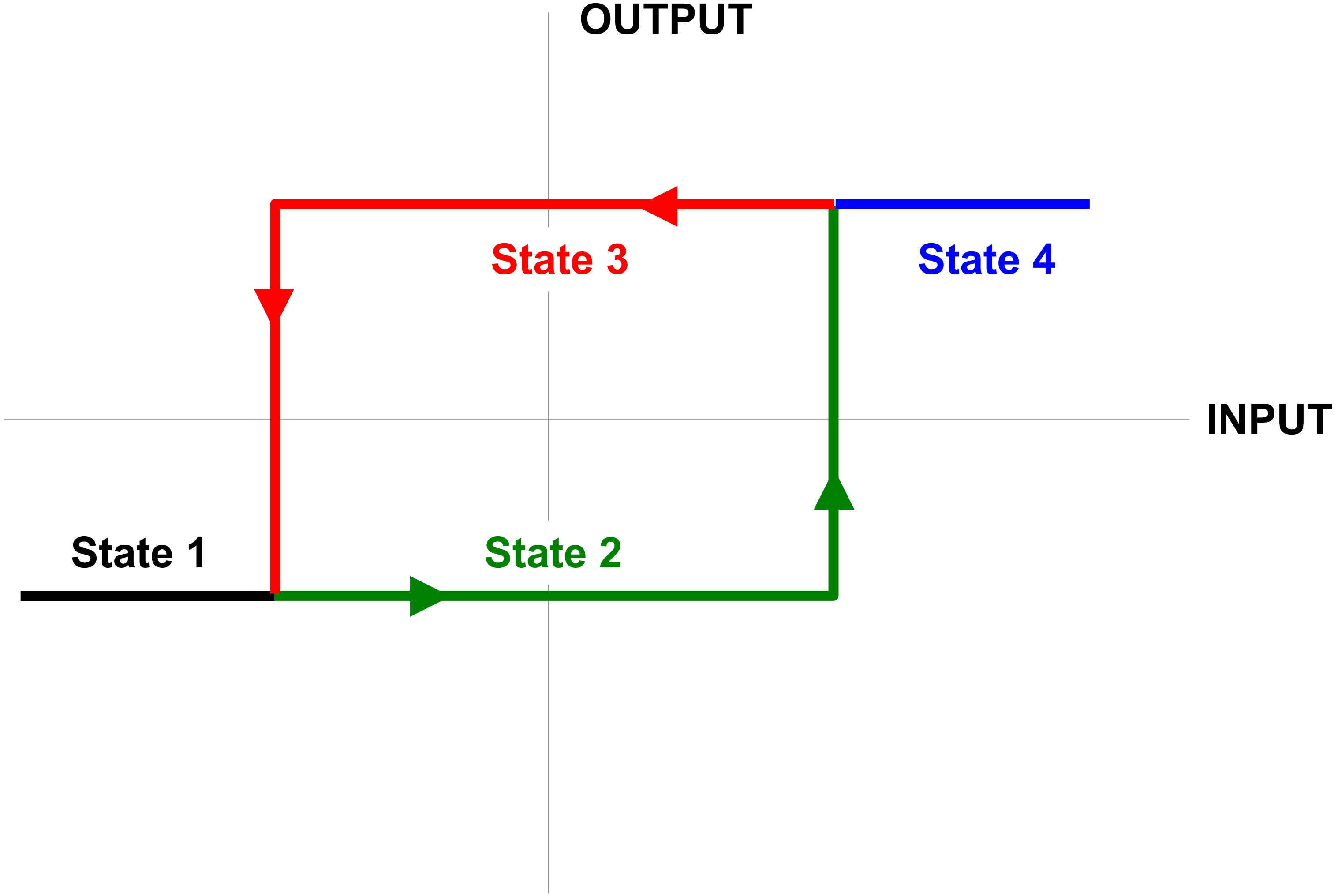


HYSTERETIC CLOSED LOOP CONTROLLER

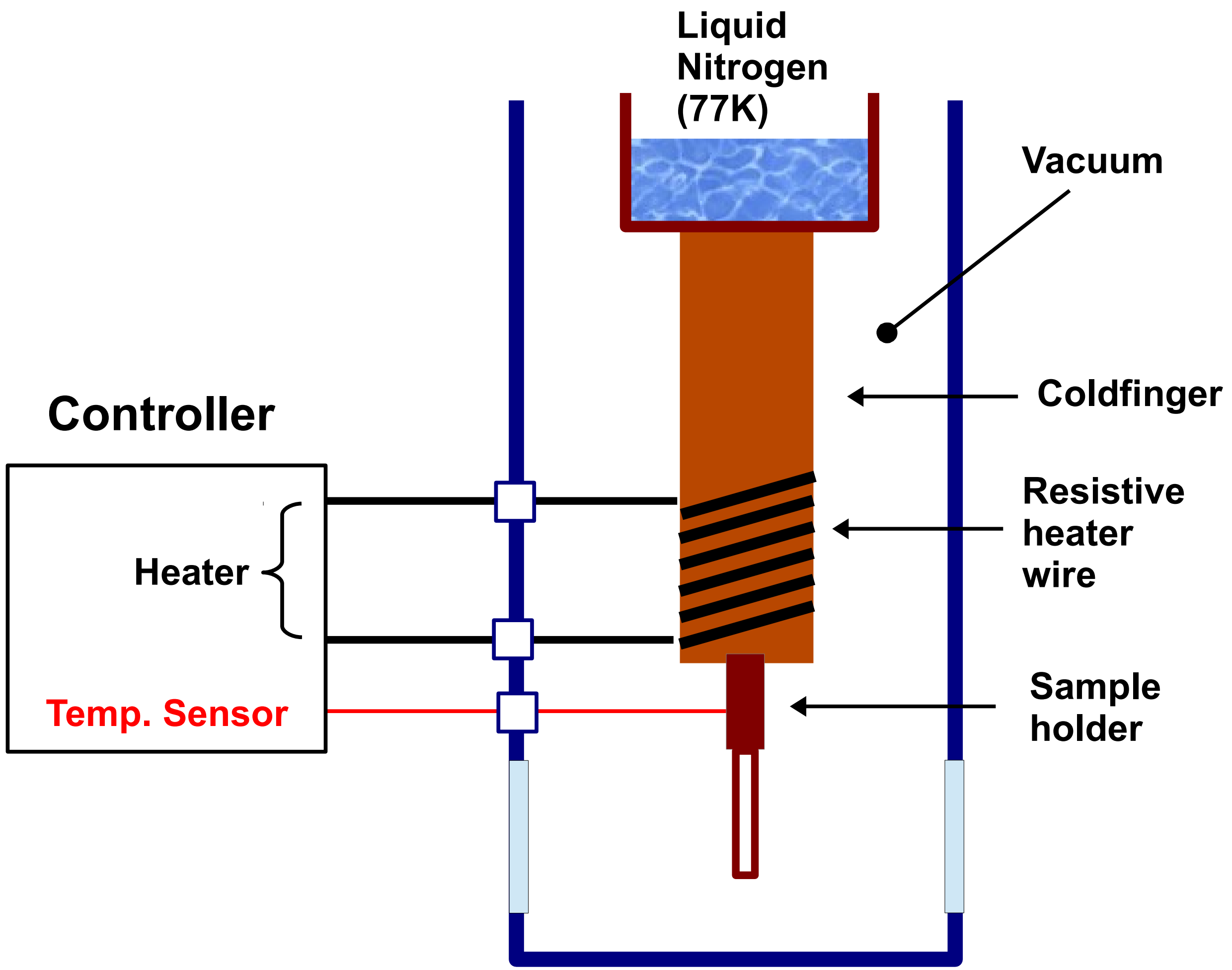


OUTPUT state depends on direction of INPUT state

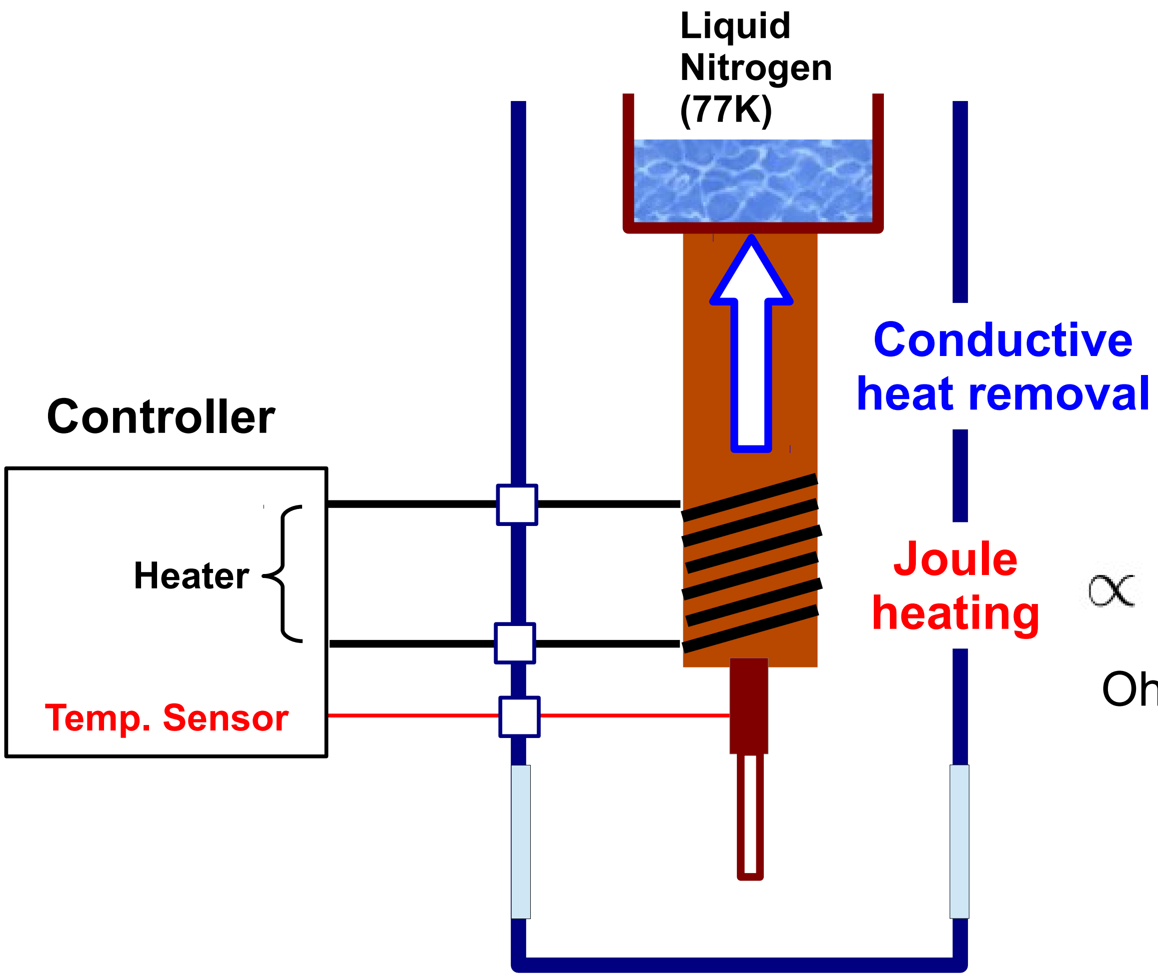
HYSTERETIC CLOSED LOOP CONTROLLER



Cryostat Temperature Controller



Cryostat Temperature Controller

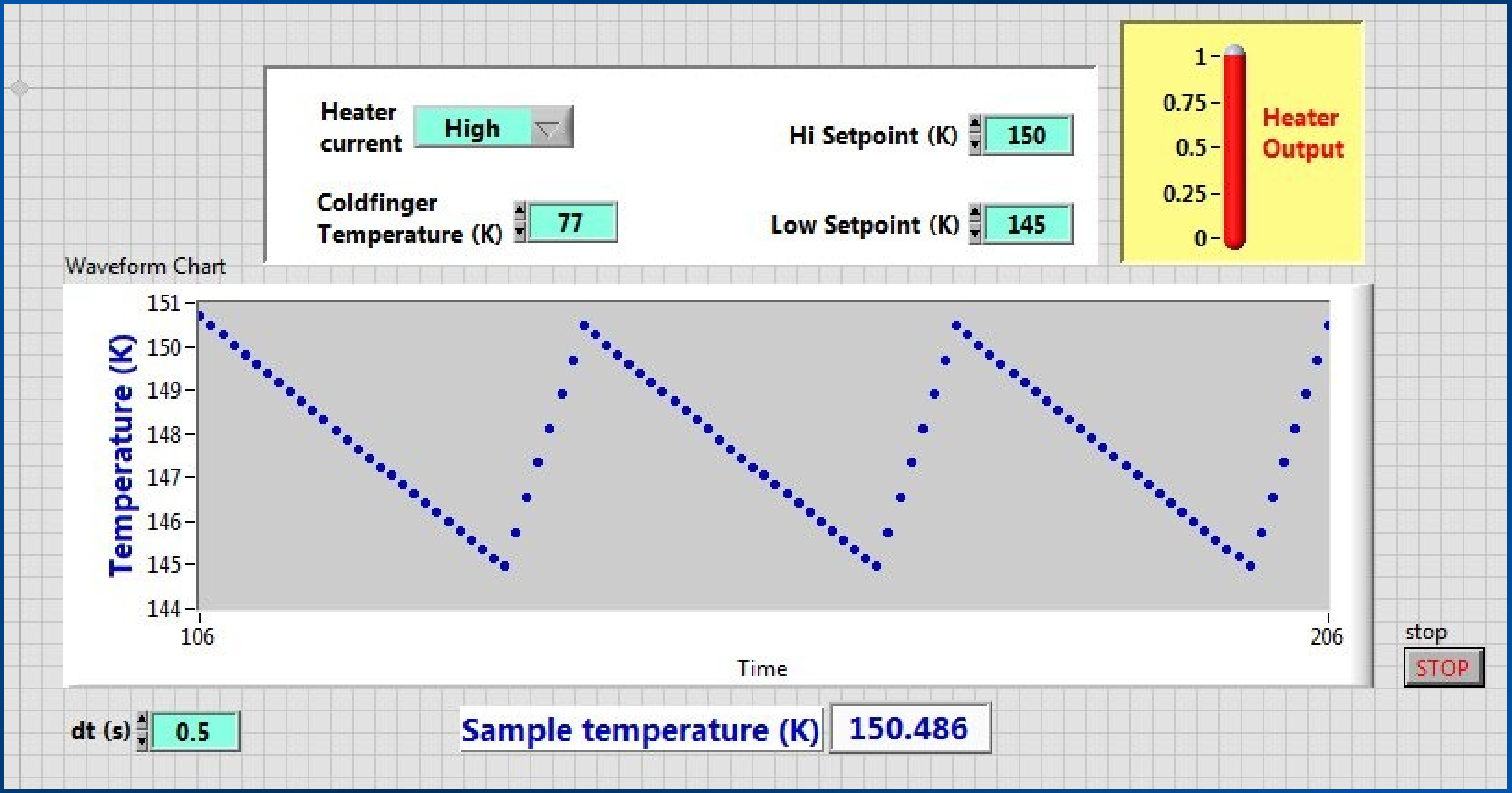


$$\propto \nabla T = \frac{dT}{dz} = k\Delta T$$

Fourier's Law

$$\propto I^2 R$$

Ohm's Law



Heater current
High
Hi Setpoint (K)
150
Coldfinger Temperature (K)
77
Low Setpoint (K)
145
1
0.75
0.5
0.25
0
Heater Output
Waveform Chart
151
150
149
148
147
146
145
144
Temperature (K)
106
206
Time
stop
STOP
dt (s)
0.5
Sample temperature (K)
150.486