ECE/CS 5780/6780: Embedded System Design

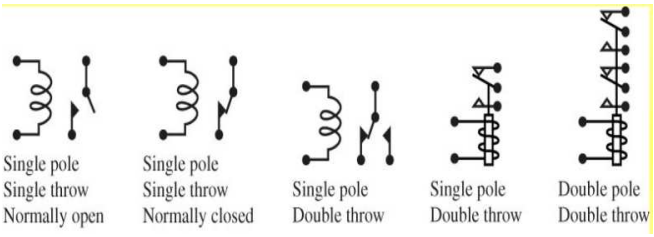
Chris J. Myers

Lecture 15: Relays and Motors

Introduction to Relays

- A relay is a device that responds to a small current or voltage change by activating a switches or other devices.
- Used to remotely switch signals or power.
- Input control usually electrically isolated from output.
- Input signal determines whether switch is open or closed.

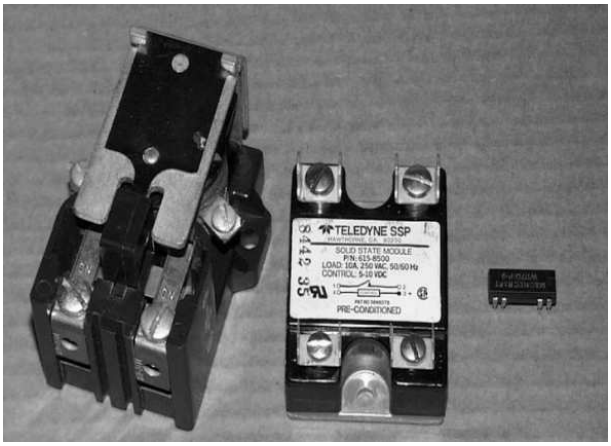
Various Relay Configurations



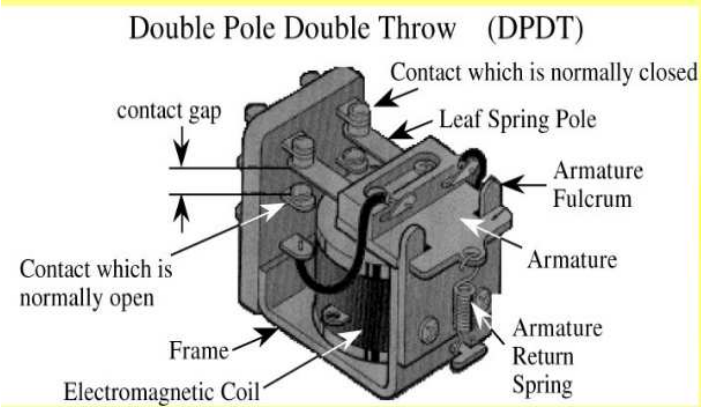
Types of Relays

- Classic general-purpose relays have EM coils and can switch power.
- Solid-state relays (SSR) have input-triggered semiconductor switches.
- Reed relay has an EM coil and can switch low level DC signals.
- The bilateral switch uses CMOS, FET, or biFET transistors (technically not a relay but behaves similarly).

Types of Relays



Drawing of an EM Relay



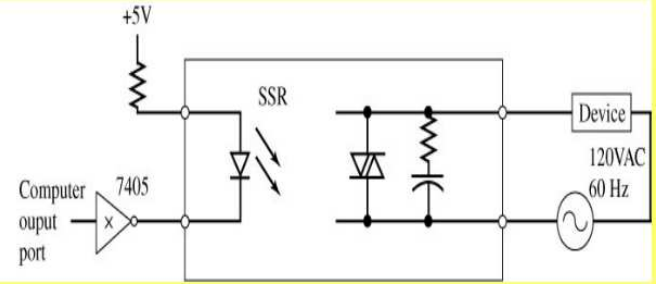
Electromagnetic Relay Basics

- Input circuit is an EM coil with an Iron Core.
- Output switch includes two sets of silver or silver-alloy contacts (*poles*).
- One set is fixed to the relay *frame*, and other is located at end of leaf spring poles connected to the *armature*.
- Contacts held in “normally closed” position by the armature return spring.
- When input circuit energizes EM coil, a “pull-in” force is applied to the armature and “normally closed” contacts break while “normally open” contacts are made.

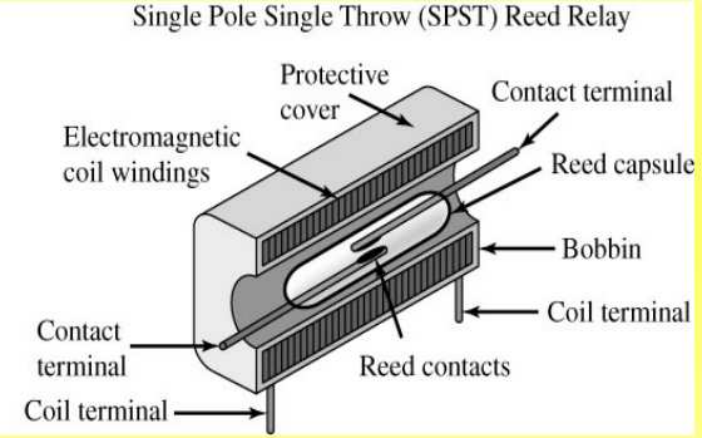
Solid State Relays

- Developed to solve limited life expectancy and contact bounce problems since they have no moving parts.
- Also, faster, insensitive to vibrations, reduced EMI, quieter, and no contact arcing.
- Optocoupler provides isolation between the input circuit (pseudocoil) and the triac (pseudocontact).
- Signal from phototransistor triggers the output triac so that it switches the load current.
- Zero-voltage detector triggers triac only when AC voltage is zero, reducing surge currents when triac is switched.
- Once triggered, triac conducts until next zero crossing.

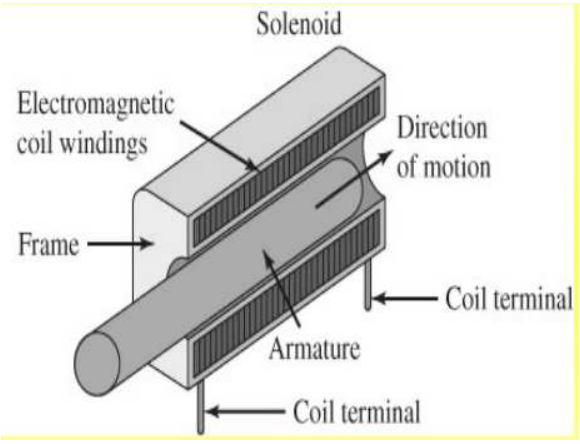
Solid State Relays



Reed Relays



Solenoids



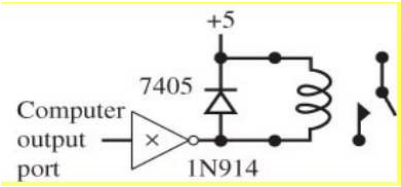
Pulse-Width Modulated DC Motors

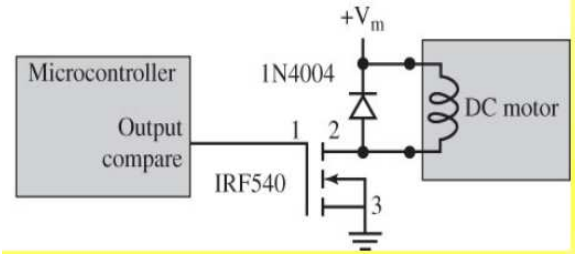
- DC motor also has frame that remains motionless and an armature that moves in this case in a circular manner.
- When current flows through EM coil, magnetic force created that causes rotation of the shaft.
- Brushes positioned between frame and armature used to alternate the current direction through the coil so that a DC current generates a continuous rotation of the shaft.
- When current removed, shaft is free to rotate.
- Pulse-width modulated DC motor activated with fixed magnitude current but duty cycle varied to control speed.

Interfacing EM Relays, Solenoids, and DC Motors

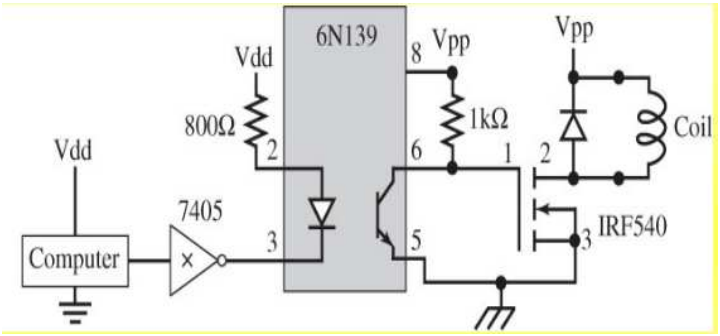
- Interface circuit must provide sufficient current and voltage to activate the device.
- In off state, input current should be zero.
- Due to inductive nature of the coil, huge back electromotive force (EMF) when coil current is turned off.
- Due to high speed transistor switch, there is a large *di/dt* when the coil is deactivated (activation also but smaller).
- Voltages can range from 50 to 200V.
- To protect the driver electronics, a snubber diode is added to suppress the back EMF.

Relay and Motor Interfaces

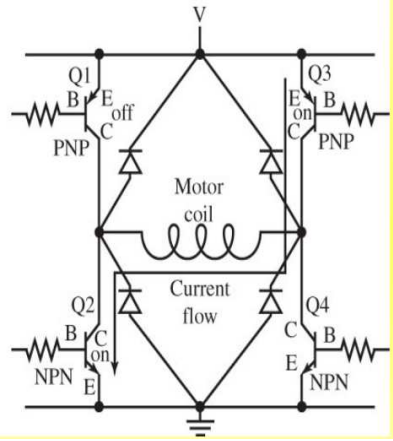




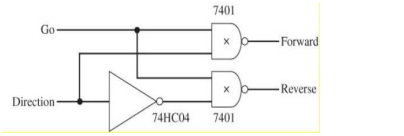
Isolated Interfaces

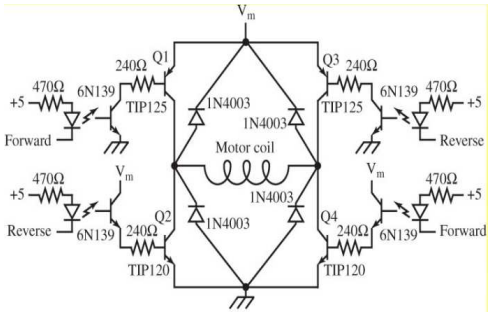


H-Bridge



Isolated H-Bridge with Direction Control

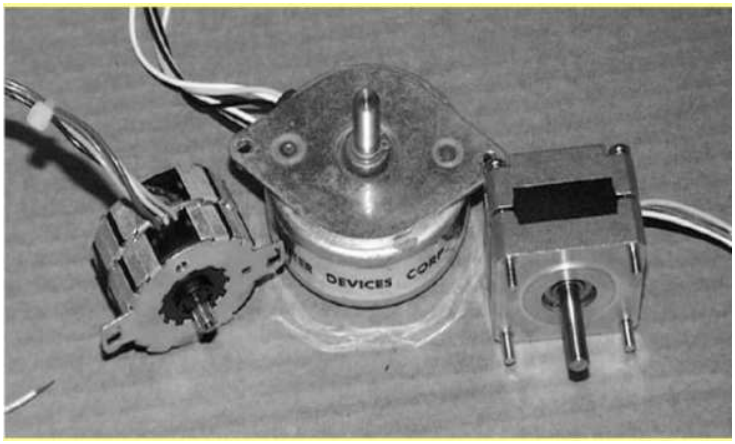




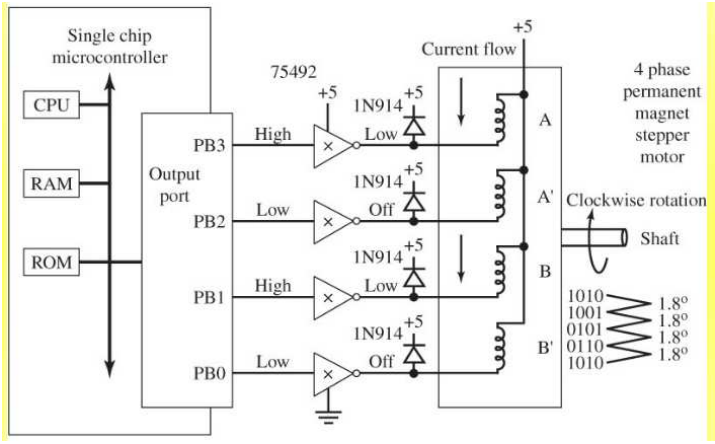
Stepper Motors

- Very popular due to inherent digital interface.
- Easy to control both position and velocity in an open-loop fashion.
- Though more expensive then ordinary DC motors, system cost is reduced as they require no feedback sensors.
- Used in disk drives and printers.
- Can also be used as shaft encoders to measure both position and speed.

Stepper Motors



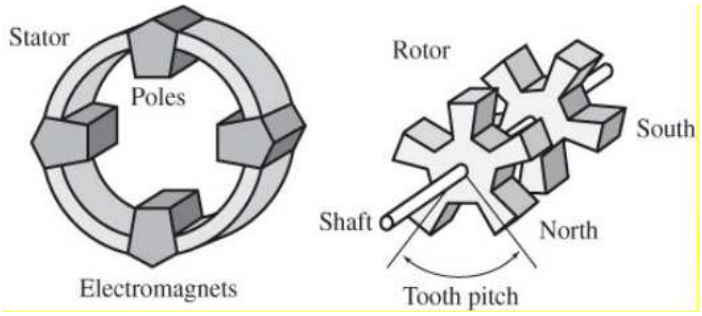
Simple Stepper Motor Interface



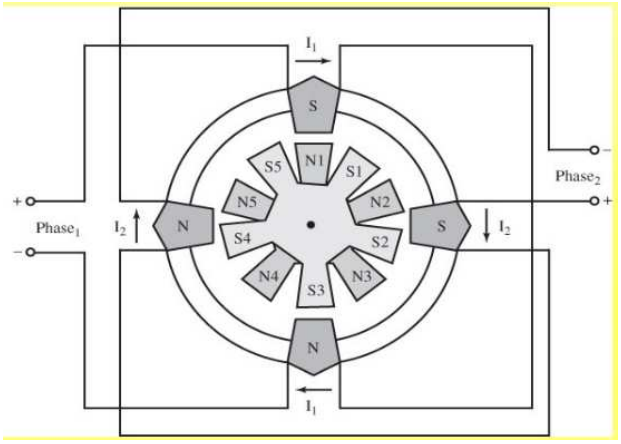
Stepper Motor Sequence

PortB	A	A'	B	B'
10	Activate	deactivate	activate	deactivate
9	Activate	deactivate	deactivate	activate
5	Deactivate	activate	deactivate	activate
6	Deactivate	activate	activate	deactivate

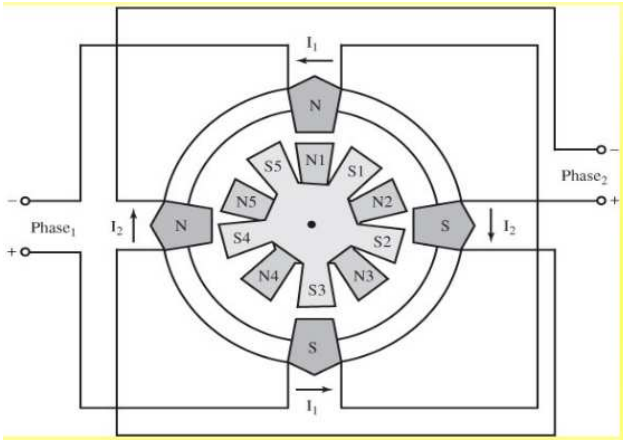
Stepper Motor Basic Operation



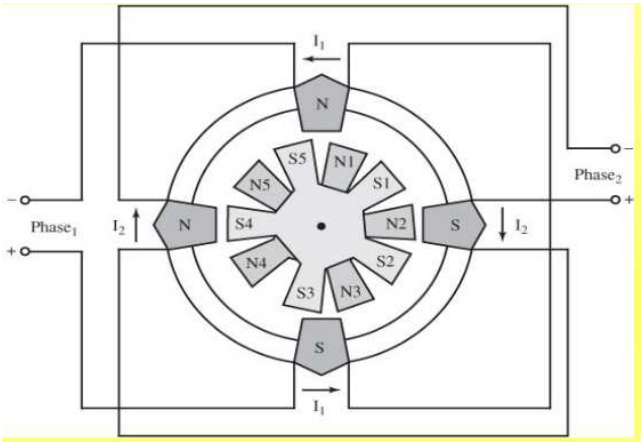
Stepper Motor Basic Operation (cont)



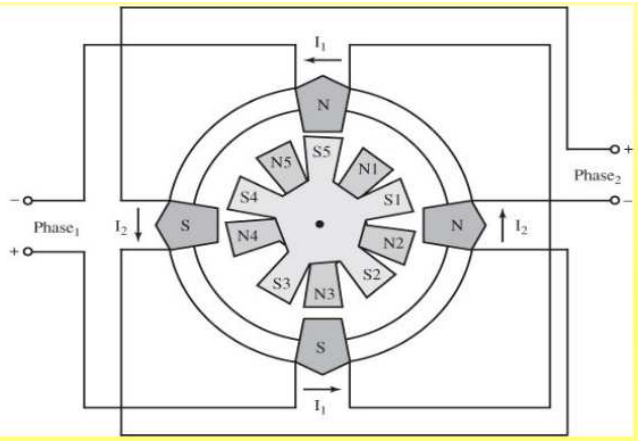
Stepper Motor Basic Operation (cont)



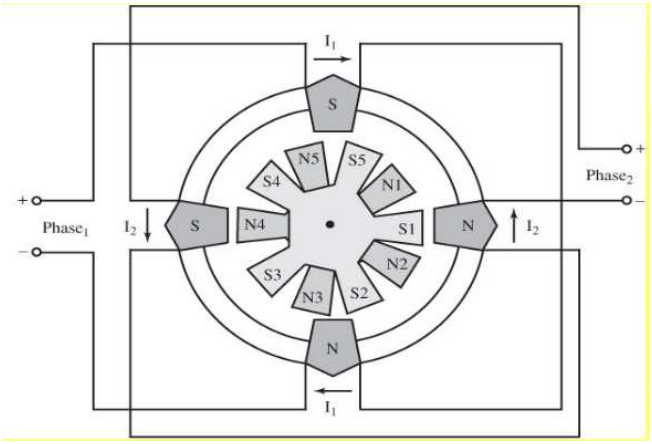
Stepper Motor Basic Operation (cont)



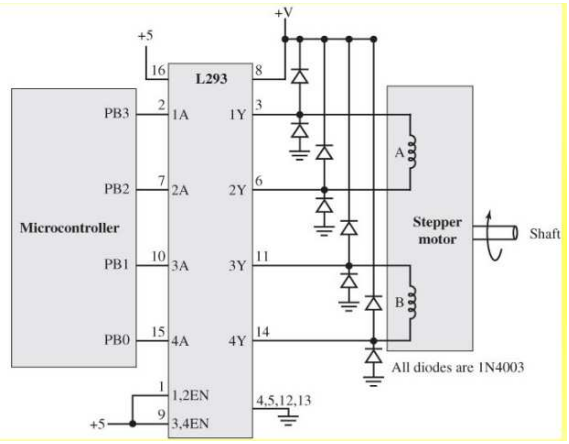
Stepper Motor Basic Operation (cont)



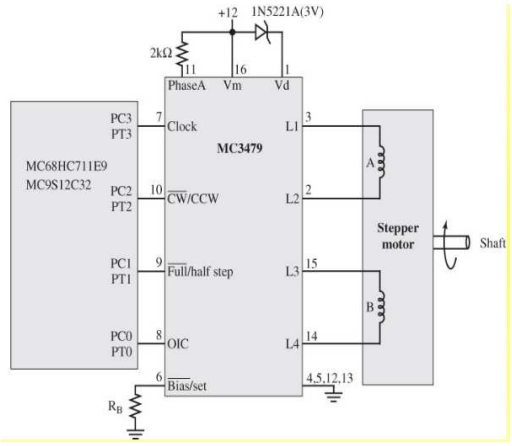
Stepper Motor Basic Operation (cont)



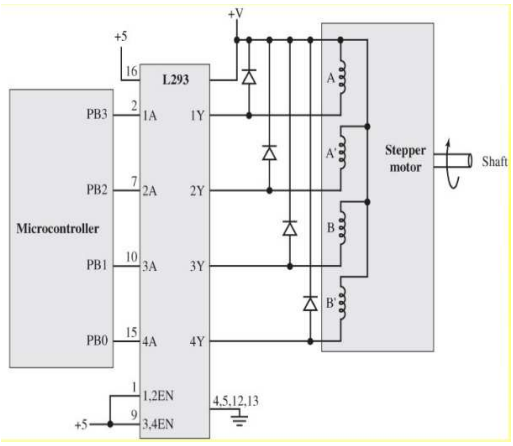
Bipolar Stepper Motor Interface



Another Bipolar Stepper Motor Interface

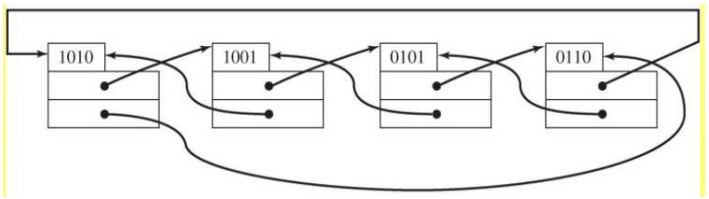


Unipolar Stepper Motor Interface



Slip

- A *slip* is when computer issues a sequence change, but the motor does not move.
- Occurs if load on shaft exceeds available torque of motor.
- Can also occur if computer changes output too fast.
- If initial shaft angle known and motor never slips, computer can control shaft angle and speed without position sensor.



Data Structures to Control Stepper Motor

```
const struct State{
  unsigned char Out;           // Output
  const struct State *Next[2]; // CW/CCW
};
typedef struct State StateType;
typedef StateType *StatePtr;
#define clockwise 0        // Next index
#define counterclockwise 1 // Next index
StateType fsm[4]={
 {10,{&fsm[1],&fsm[3]}},
 { 9,{&fsm[2],&fsm[0]}},
 { 5,{&fsm[3],&fsm[1]}},
 { 6,{&fsm[0],&fsm[2]}}};
unsigned char Pos;  // between 0 and 199
StatePtr Pt;        // Current State
```


Ritual to Control Stepper Motor

```
void Init(void){
  Pos = 0;
  Pt = &fsm[0];
  DDRB = 0xFF;
}
```

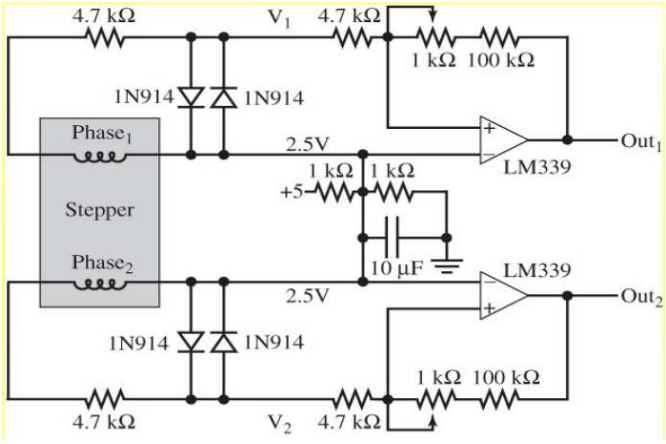

Helper Functions to Control Stepper Motor

```
void CW(void){
  Pt = Pt->Next[clockwise]; // circular
  PORTB = Pt->Out;          // step motor
  if(Pos==199){             // shaft angle
    Pos = 0;                // reset
  }else{
    Pos++;}}                // CW
void CCW(void){
  Pt = Pt->Next[counterclockwise];
  PORTB = Pt->Out;          // step motor
  if(Pos==0){               // shaft angle
    Pos = 199;              // reset
  }else{
    Pos--;}}                // CCW
```


High-Level Control of Stepper Motor

```
void Seek(unsigned char desired){
short CWsteps;
  if((CWsteps=desired-Pos)<0){
    CWsteps+=200;
  } // CW steps is 0 to 199
  if(CWsteps>100){
    while(desired!=Pos){
      CCW();
    }
  }
  else{
    while(desired!=Pos){
      CW();
    }
  }
}
```

Stepper Motor as Shaft Position Sensor



Timing of Stepper Motor as Shaft Position Sensor