Electrical & Computer ENGINEERING

18-642:
Modal Systems & Statecharts

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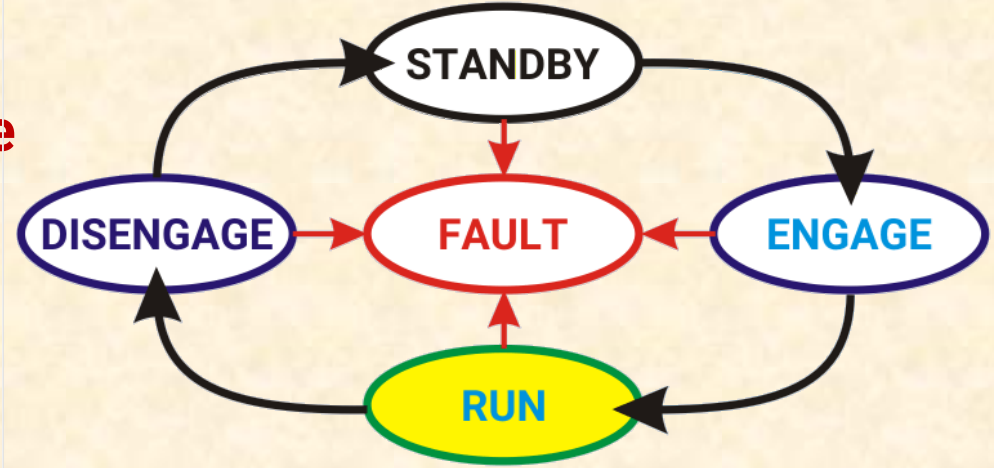
State Intensive Systems

- **Anti-Patterns:**
  - **No detailed design – just code**
  - **Deeply nested if statements instead of switch statements for state-full code**
  - **Mixing mode change logic with normal output sequences**



- **Detailed design of state-intensive behaviors**
  - Operating modes, e.g., stop, start, run
  - Inputs that drive sequences of events
  - Key technique: statecharts (software finite state machine)

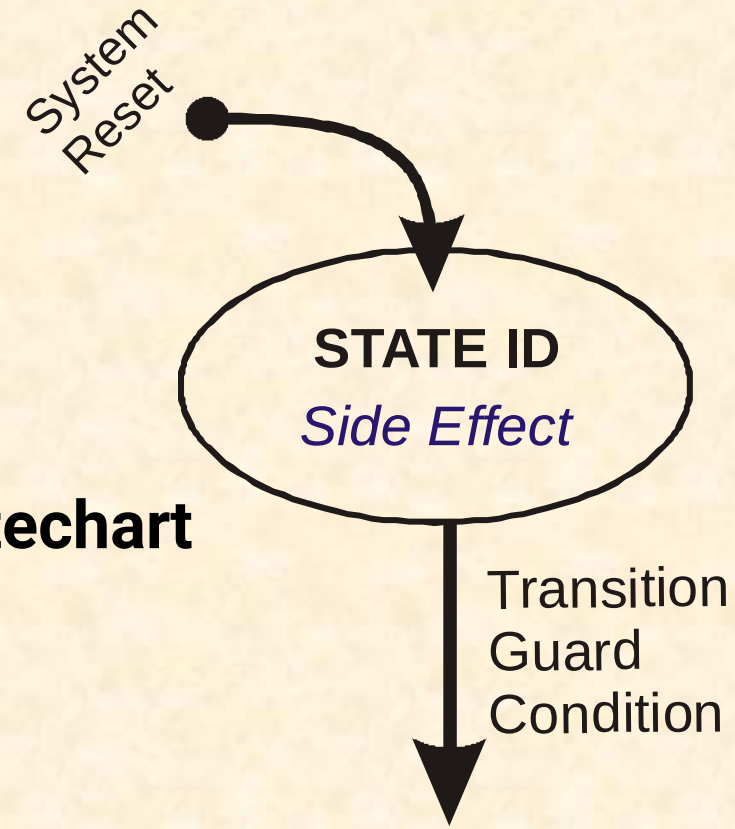
3-Speed Fan FlowChart

- **Example code for 3-speed fan**
  - Draw a flowchart -- how easy is it to understand this code?
  - Are there any bugs in this code?

```
// SPDBUTTON:  input true on cycle when speed button depressed
// ONOFF: input true one cycle when on/off switch depressed
static uint8_t speed; // 0=off; 1=slow; 2=medium; 3=fast
…..
if(speed == 0)
{ if(SPDBUTTON == 1 || ONOFF == 1) { speed = 1; }
} else if (SPDBUTTON == 1)
{ if (speed == 1) { speed = 2; }
  else if (speed == 2) { speed = 3;}
  else { speed = 0;}
} else if (ONOFF == 1)
{ speed = 0;}
```

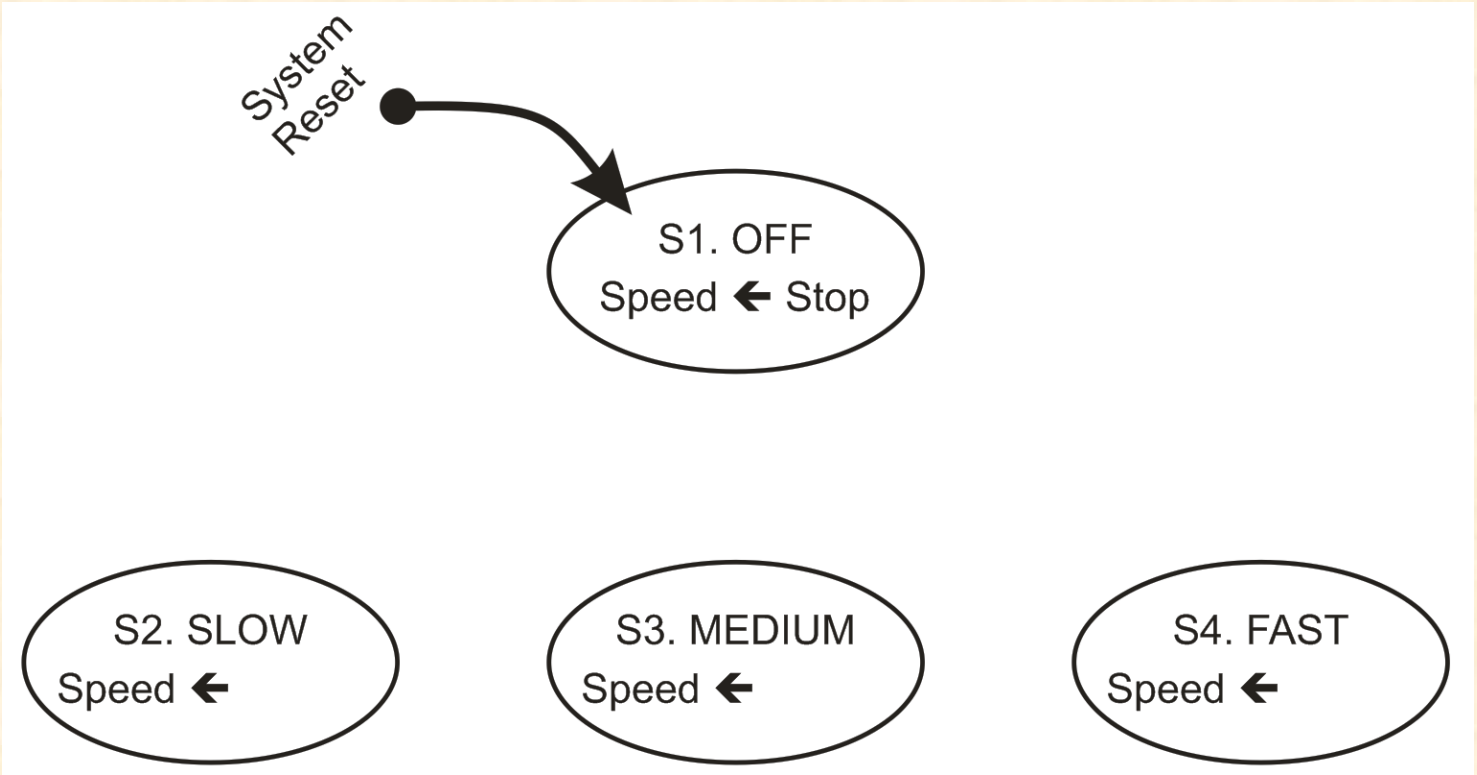
Elements of a Statechart

- **A statechart is a software Finite State Machine:**
  - Set of states with side effects
  - Set of guards that cause transitions
    - No side effects on transitions
  - Initial state
- **Convert example fan code to statechart**
  - (Next slide has graphic)
  - Define a state for each fan speed
  - Define transitions
  - Easier to understand? Any bugs?

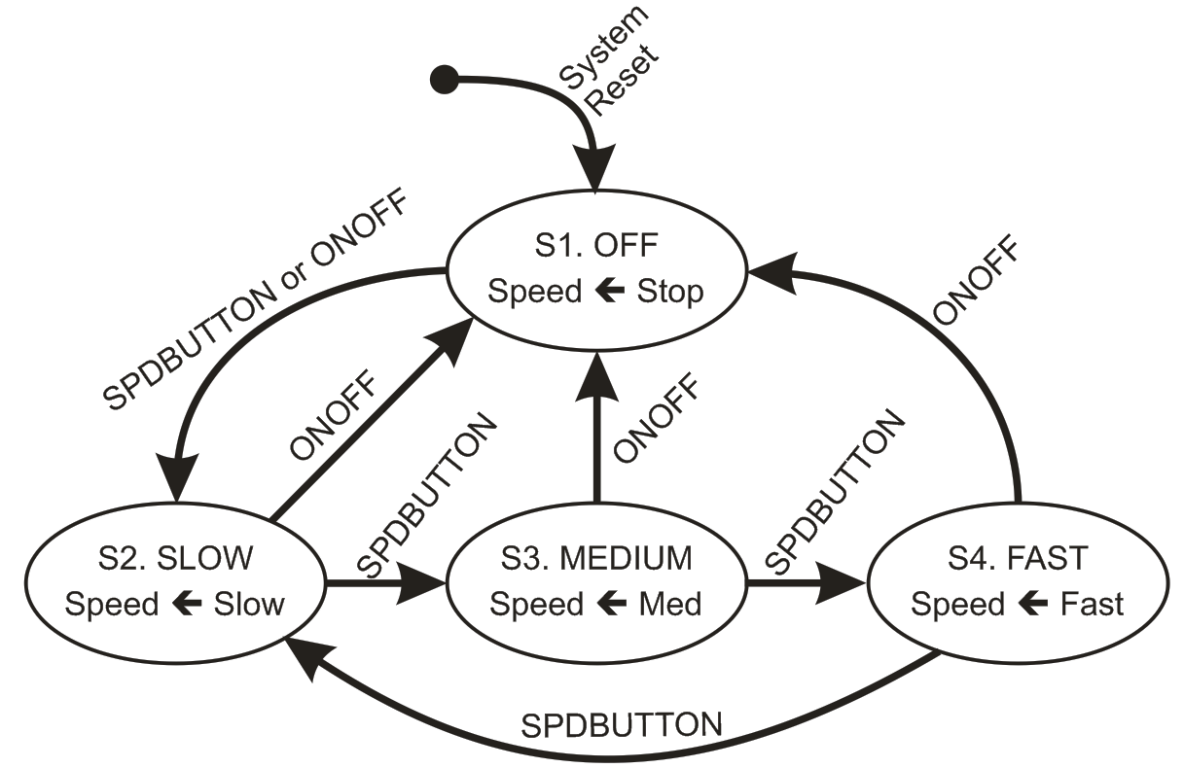


Convert to StateChart Exercise: 3-speed fan

- **Define initial state, side effects, transitions**



Corrected Statechart



- **This is a controller for a multi-speed motor or other similar application**
  - Inputs: SPDBUTTON, ONOFF
  - Outputs: Speed = {Stop, Slow, Med, Fast}
  - State names (arbitrary labels): {OFF, SLOW, MEDIUM, FAST}
  - System Reset is to state s1

Fan Example Code – part 1

```
static enum CurrState {OFF, SLOW, MEDIUM, FAST}; // define states
static const uint8_t SpdOff=0; // define speed constant values
static const uint8_t SpdSlow=10;
static const uint8_t SpdMed=15;
static const uint8_t SpdFast=25;
CurrState = OFF; // initialize state machine to OFF
void ProcessStates(void) // run periodically from main loop
{ switch (CurrState)
  { case OFF: // State S1
      speed(SpdOff); // Take action in state
      // Test arc guards and take transitions
      if (SpdButton() == TRUE || OnOffButton() == TRUE) {CurrState = SLOW;}
      break; // go to end of switch statement
   case SLOW: // State S2
      speed(SpdSlow); // take action
      if (SpdButton() == TRUE) {CurrState = MEDIUM;}
      if (OnOffButton() == TRUE) {CurrState = OFF;}
      break;
```

Fan Example Code – part 2

```
   case MEDIUM: // State S3
     speed(SpdMed); // take action
     if (SpdButton() == TRUE) {CurrState = FAST;}
     if (OnOffButton() == TRUE) {CurrState = OFF;}
     break;
    case FAST: // State S4
     speed(SpdFast); // take action
     if (SpdButton() == TRUE) {CurrState = SLOW;}
     if (OnOffButton() == TRUE) {CurrState = OFF;}
     break;
    default: // Error: invalid state
     error(INVALID_STATE_ERROR); // should never get here
  }
}
```

Best Practices for Statecharts

- **Use statecharts for stateful code**
  - Maps to easier-to-test switch statement
  - Avoid actions on arcs to simplify code
  - Move complex behaviors to per-state subroutine helper functions to limit cyclomatic complexity

https://goo.gl/ocnSRS

- **Summary of pitfalls**
  - Some code is better as flowchart if there is no state history
  - Don't let statechart get too complex
    - Might need to decompose into nested or parallel state machines