Midterm Exam Statistics

- Mean Score = 62
- Median Score = 62
- High Score = 86
- Distribution

80s = 5
70s = 3
60s = 11
50s = 9
<50 = 8

Note: A solution will be posted on the class web site.

Final Project

- Conducted during the last three weeks of class
- Assignment: Design and implement an embedded application of your choosing
- Constraint: Your system must include at least one of the following:
  - Use of a PIC feature not used in labs—e.g. CCP unit
  - Use of a protocol not used in labs—e.g. I^2C
  - Use of a peripheral chip not used in lab
- Scope/complexity of your application must be at least comparable to that of lab 5 and lab 6.
- Stretch yourselves--more points will be awarded to more ambitious projects
- Project proposals will be due on **Tues. April 10**

Designing an Embedded Application—Lab 5 as an Example

55:036

Embedded Systems and Systems Software

Lab 5—Major Elements

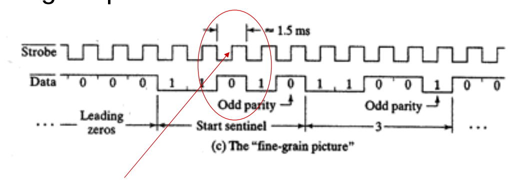
- Read User-IDs from Mag Stripe reader
- Read PINs from Keypad
- Compare the entered USER-IDs and PINs to values pre-stored in on-board EEPROM
- Display text on LCD
- Check for pushbutton presses
- Update stored PINs (in EEPROM)

Where Do We Start?

- Central issues: use of timers, other devices, interrupts
- Usually a good idea to consider timing constraints first
- This will dictate the overall structure of the application

Lab 5—Timing Constraints

- Mag Stripe Reader



Nominal data rate: 1.5 msec/bit (= 667 Hz)

Data must be sampled within approx. 0.75 msec. after leading edge of strobe

Lab 5—Timing Constraints

- Keypad:
  - Switch debounce requires sampling keypad at approx. 10 msec. intervals
  - Variation of a few msec. in either direction can be tolerated
- Pushbutton switch:
  - Debounce shouldn't be an issue since we are just checking for evidence a button push.
  - Only interested in button pushes that occur within 5 seconds of authorization

Lab 5—Timing Constraints

- LCD
  - Writing a character to the LCD requires approx. 45 microseconds
  - Need to insure that programmed delays don't interfere with servicing of other devices
    - e.g. Writing 16 characters to the LCD requires approx. 0.7 milliseconds

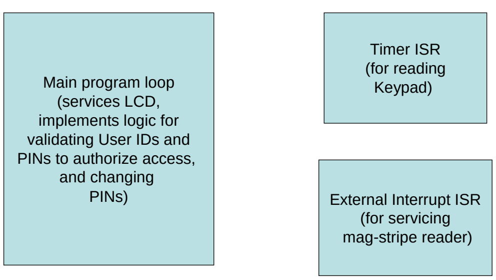
So, How Should Lab 5 be Structured?

- Main Program Loop:
  - Authorize Users
    - Check entered User-ID/PIN against values stored in EEPROM
  - Handle PIN updates
  - service LCD
- Mag. Stripe Reader
  - Service via external interrupt
  - Should be OK to trigger interrupts on leading edge of strobe.
- KeyPad
  - Service via periodic timer interrupt
  - 10 msec. period should work OK

Interrupt Priorities

- It should be OK to configure both external interrupts and timer interrupts as low priority.
- timing constraints for both devices are fairly flexible
- No particular advantage to giving one priority over the other
- Both ISRs will be short
- Shouldn’t interfere too much with each other
- Will need to use polling to determine which interrupt has occurred
- Alternatively, can assign one device high priority and the other low priority.

Lab 5 Program Structure



Designing the Mag-Stripe Reader ISR

- This ISR will be invoked at leading-edge of each strobe cycle (approx the middle of each data bit period) from the mag-stripe reader
- ISR needs to sample the data line from the mag-stripe reader and assemble and store digits read from track 2

Track 2 Format

Odd Parity	b3	b2	b1	b0		Meaning of Group
0	1	0	1	1	b	Start sentinel
1	0	0	1	1	3	First data character
0	0	0	0	1	1	Second data character
0	0	0	1	0	2	Third data character
1	0	1	0	1	2	Fourth data character
		• • •				
0	0	1	1	1	7	Last data character
1	1	1	1	1	f	End sentinel
1	0	1	0	0		LRC character

Track 2 data characters are 4 bits + parity. (Must be numeric: 0x0 – 0x9)

Characters are recorded LSB first with parity at the end --i.e. right to left in this diagram

Designing the Mag-Stripe Reader ISR

- General Idea
  - Identify the beginning of the "start sentinel"
  - Assemble next four bits into a digit and store in an array
  - read the parity bit and discard (or verify correct parity)
  - Continue to assemble and store digits as above until the 10-digit User-ID, stop sentinel, and LRC character have been read

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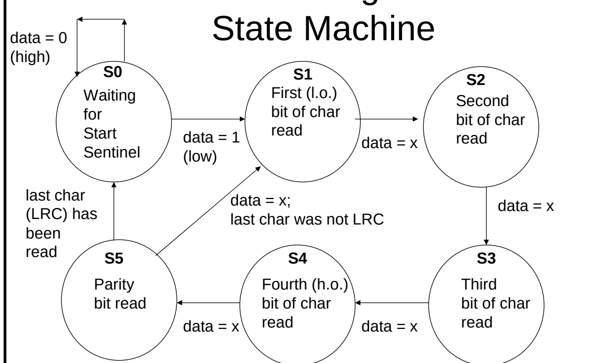
But, remember, this behavior takes place over many invocations of the ISR—the ISR is invoked once for each bit-time on the card

A Useful Structuring Tool—Finite State Machine



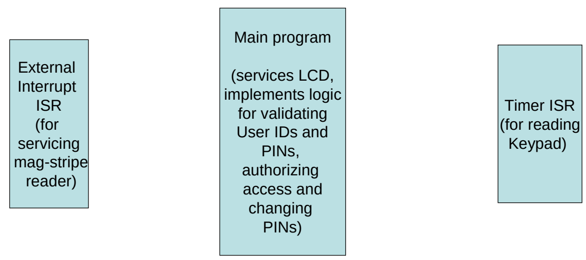
Note: Structure the Mag-reader ISR as a FSM—one state transition per invocation

Implementing the FSM

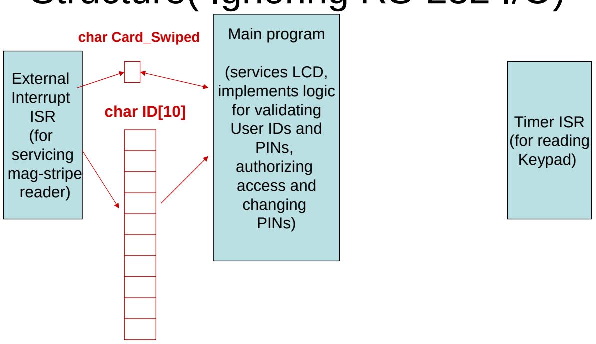
```
#define S0    0
#define S1    1
#define S2    2
#define S3    3
#define S4    4
#define S5    5
char next_state = S0;
char current_bit;
char next_bit;
char ch;
char User_ID[12];

Mag_Stripe_ISR() {
    current-bit = next_bit
    next_bit = /* data value read from Mag stripe rdr */
    switch (next_state)  {
      S0:
        if (next_bit == 0) next_ state = S0;
        else next_state = S1;
        break;
      S1:
        /* do S1 stuff here */
        next_state = S2;
        break;
      S2:
        /* do S2 stuff here */
        next_state = S3;
        break;
      S3:
        /* do S3 stuff here */
        next_state=S4;
        break;
      S4:
        /* do S4 stuff here */
        next_state=S5;
        break;
      S5:
        /* do S5 stuff here */
        if (/* 12 chars have been read */)
          next_state = S0;
        else  next_state = S1;
    }  // end switch
} // end of ISR
```

Possible Lab 5 Program Structure

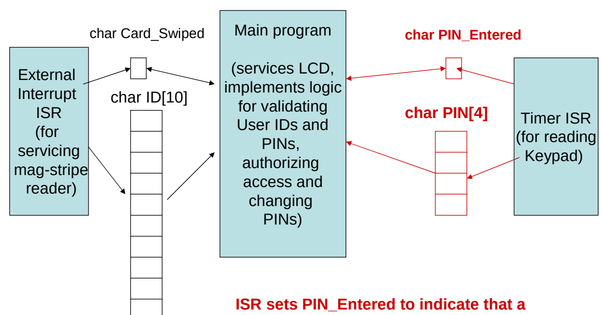


Possible Lab 5 Program Structure(Ignoring RS-232 I/O)



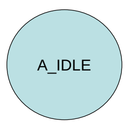
ISR sets Card_Swiped to indicate that a complete User-ID has been read from a card. The User-ID is placed by the ISR into the array ID

Possible Lab 5 Program Structure

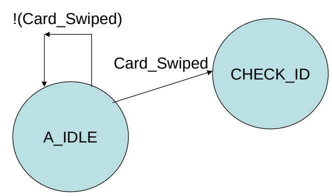


ISR sets PIN_Entered to indicate that a complete PIN has been read from the keypad. The PIN is placed by the ISR into the array PIN

Main Program as a FSM



Main Program as a FSM
(Ignoring PIN Change Logic)



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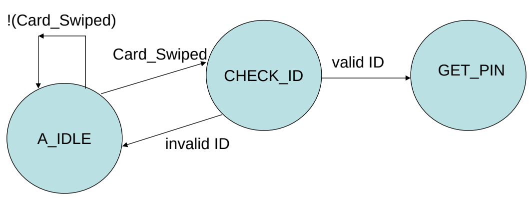

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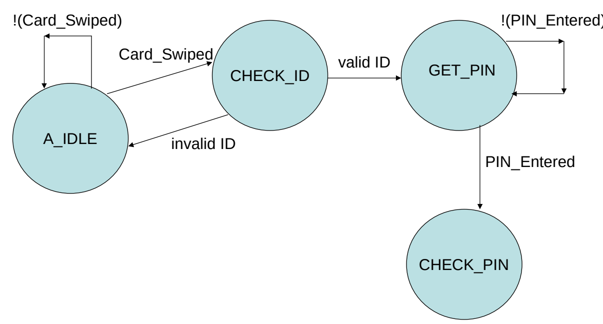
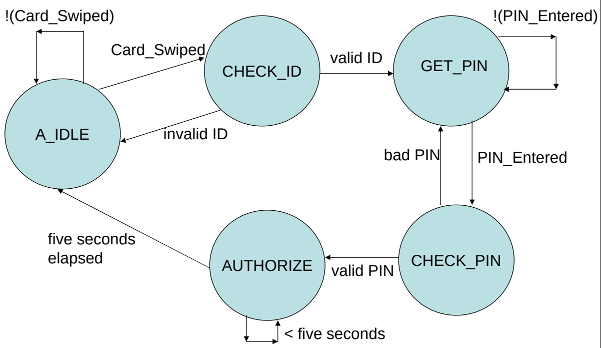


Main Program as a FSM (Ignoring PIN Change Logic)



Pseudo-Code for Main FSM states

```
main () {
  //Initialization Goes Here
  while(1)
    switch (Auth_Next_State) {
      A_IDLE:
        /* A_IDLE State Stuff Goes Here */ break;
      CHECK_ID:
        /* CHECK_ID State Stuff Goes Here */ break;
      GET_PIN:
         /* GET_PIN State Stuff Goes Here */ break;
      CHECK_PIN:
        /* CHECK_PIN State Stuff Goes Here */ break;
      AUTHORIZE:
        /* AUTHORIZE State Stuff Goes Here */
    }
```

Pseudo-Code for Main FSM states

```
Initialization:
  Display “Swipe Card” on LCD;
  Turn off Authorization LED;
  Card_Swiped = false;
  PIN_Entered = false;
  Auth_Next_State = A_IDLE;
```

Pseudo-Code for Main FSM states

```
IDLE:
  if (Card_Swiped)
    Auth_Next_State = CHECK_ID;
  else Auth_Next_State = A_IDLE;
  break;
```

Pseudo-Code for Main FSM states

```
CHECK_ID:
  Reset Card_Swiped;
  If (ID matches a stored User-ID) {
     Stored_PIN = PIN of matching stored User-ID;
     Display "Enter PIN" on LCD;
     Auth_Next_State = GET_PIN;
     }
  else {
     Display "Invalid ID" on LCD
     Auth_Next_State=A_IDLE;
     }
  break;
```

Pseudo-Code for Main FSM states

```
GET_PIN:
  if (PIN_Entered)
     Auth_Next_State = CHECK_PIN;
  else
     Auth_Next_State = GET_PIN;
  break;
```

Pseudo-Code for Main FSM states

```
CHECK_PIN:
  If (PIN == Stored_PIN) {
     Turn on Authorization LED;
     Display " Door is Unlocked" on LCD;
     Auth_Next_State = Authorize;
     }
  else {
     Display "Re-enter PIN" on LCD;
     Auth_Next_State = GET_PIN;
     }
   break;
```

Pseudo-Code for Main FSM states

```
AUTHORIZE:
  If ( less than five seconds have elapsed since entering
       this state)
     Auth_Next_State = AUTHORIZE;
  else  {
     Turn off authorization LED;
     Display "Swipe Card" on LCD;
     Auth_Next_State = A_IDLE;
     }
  break:
```

Discussion

- You will need to add in the “Change PIN” functionality
- This will require extensions to the Main FSM
- Need to carefully review timing issues to make sure that there is no interference among various parts of the system.