External Interrupts, Magnetic Stripe Reader, Keypad, Data EEPROM

55:036

Embedded Systems and Systems Software

Important Reminders

- Reminder—Midterm Exam, Thursday, March 8, In class.
- Lab 5 will be posted no later than Thursday March 8
  - Prelabs will be due on the Tuesday following Spring Break
- Lab 4 Reports will be due on the Thursday following Spring Break

Midterm Exam

- Thursday, March 8, in class
- Format:
  - open book, open notes
  - no major code writing
  - may be some minor programming
    - e.g. a few lines of lines of code to show how to do some operation
    - you DO need to know the PIC instruction set
    - you DO need to understand the examples that we have discussed in class.
- Example Exam Questions
  - Look at the old exam questions posted on the www.picbook.com web site (downloads section)

Exam Coverage

- Exam will be based on material covered in lecture through Thursday, Feb. 22 and labs 1-4
- Relevant Text Chapters:

  2, 3, 5, 7, 8, 9, 11, 13(secs. 13.1-13.4 only)
- Recommended Approach to Preparing for the Exam
  - Study the lecture notes first
  - Use the text to clarify and/or expand upon topics that you don't fully understand
  - Don't use the open-book, open-notes nature of the exam as a rationale for lax preparation
    - You will need to work efficiently during the exam
    - There will not be time to learn new material on the fly

External Interrupts

- External interrupts
  - The mag-stripe reader is a "self-clocked" device
    - The rate at which data is read from the card stripe is determined by the speed at which the user is swiping the card through the reader
    - This speed can vary from 2 in/sec to 125 in/sec.
    - Hence we cannot just service the mag-stripe reader at a fixed, periodic rate
  - A strobe signal from the reader identifies the bit boundaries in the data stored on the mag-stripe
  - Will use this strobe signal to generate an interrupt each time another bit-value needs to be read from the stripe reader

PIC 18F452 External Interrupts

- Three individual external interrupts INT0 – INT2
  - Pins RB0-RB2, respectively
  - Must be configured as input
  - INT0 is high-priority only
- Interrupt on Change
  - Pins RB7:RB4
  - Interrupt generated whenever the value on any of these pins changes (relative to its value at last read of PORTB
  - Only those pins configured as inputs are considered

Name	Priority Bit	Int. Enable Bit	Int. Flag Bit
INT0 external interrupt	*	INTCON,INT0IE	INTCON,INT0IF
INT1 external interrupt	INTCON3,INT1IP	INTCON3,INT1IE	INTCON3,INT1IF
INT2 external interrupt	INTCON3,INT2IP	INTCON3,INT2IE	INTCON3,INT2IF
RB port change interrupt	INTCON2,RBIP	INTCON,RBIE	INTCON,RBIF
TMR0 overflow interrupt	INTCON2,TMR0IP	INTCON,TMR0IE	INTCON,TMR0IF
TMR1 overflow interrupt	IPR1,TMR1IP	PIE1,TMR1IE	PIR1,TMR1IF
TMR3 overflow interrupt	IPR2,TMR3IP	PIE2,TMR3IE	PIR2,TMR3IF
TMR2 to match PR2 int.	IPR1,TMR2IP	PIE1,TMR2IE	PIR1,TMR2IF
CCP1 interrupt	IPR1,CCP1IP	PIE1,CCP1IE	PIR1,CCP1IF
CCP2 interrupt	IPR2,CCP2IP	PIE2,CCP2IE	PIR2,CCP2IF
A/D converter interrupt	IPR1,ADIP	PIE1,ADIE	PIR1,ADIF
USART receive interrupt	IPR1,RCIP	PIE1,RCIE	PIR1,RCIF
USART transmit interrupt	IPR1,TXIP	PIE1,TXIE	PIR1,TXIF
Sync. serial port int.	IPR1,SSPIP	PIE1,SSPIE	PIR1,SSPIF
Parallel slave port int.	IPR1,PSPIP	PIE1,PSPIE	PIR1,PSPIF
Low-voltage detect int.	IPR2,LVDIP	PIE2,LVDIE	PIR2,LVDIF
Bus-collision interrupt	IPR2,BCLIP	PIE2,BCLIE	PIR2,BCLIF

* INT0 can only be used as a high-priority interrupt
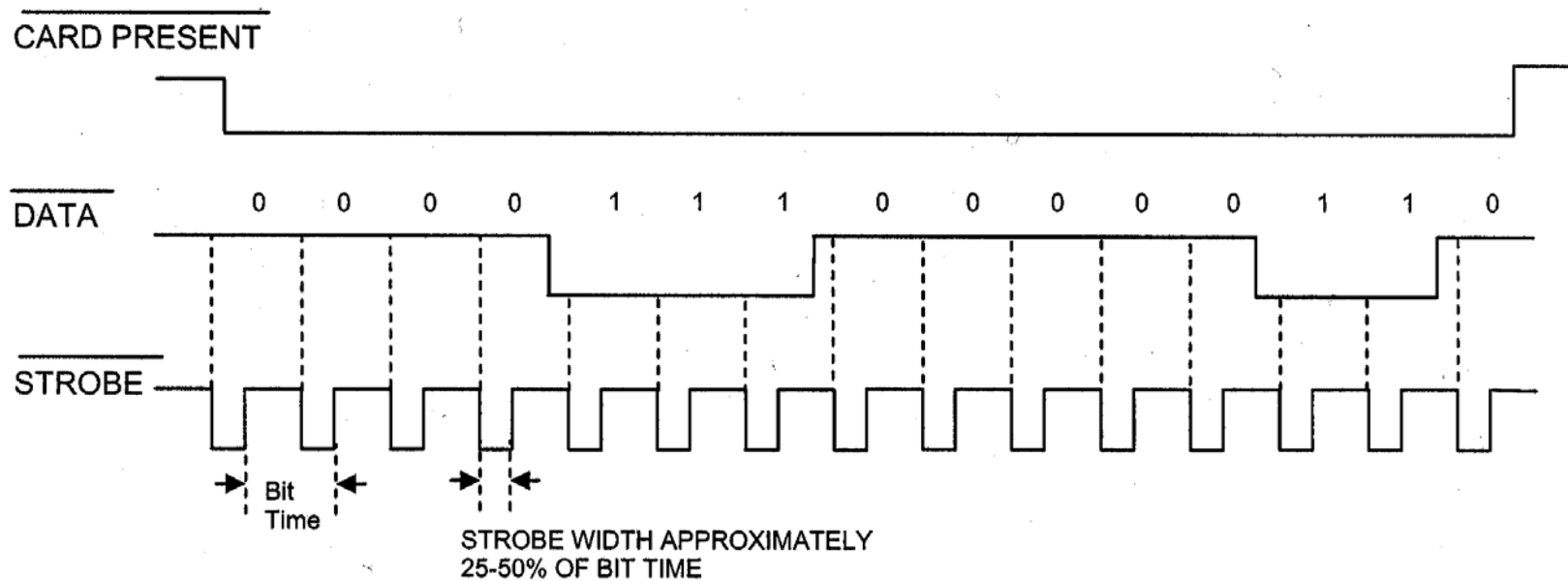
Magtek Magnetic Stripe Reader
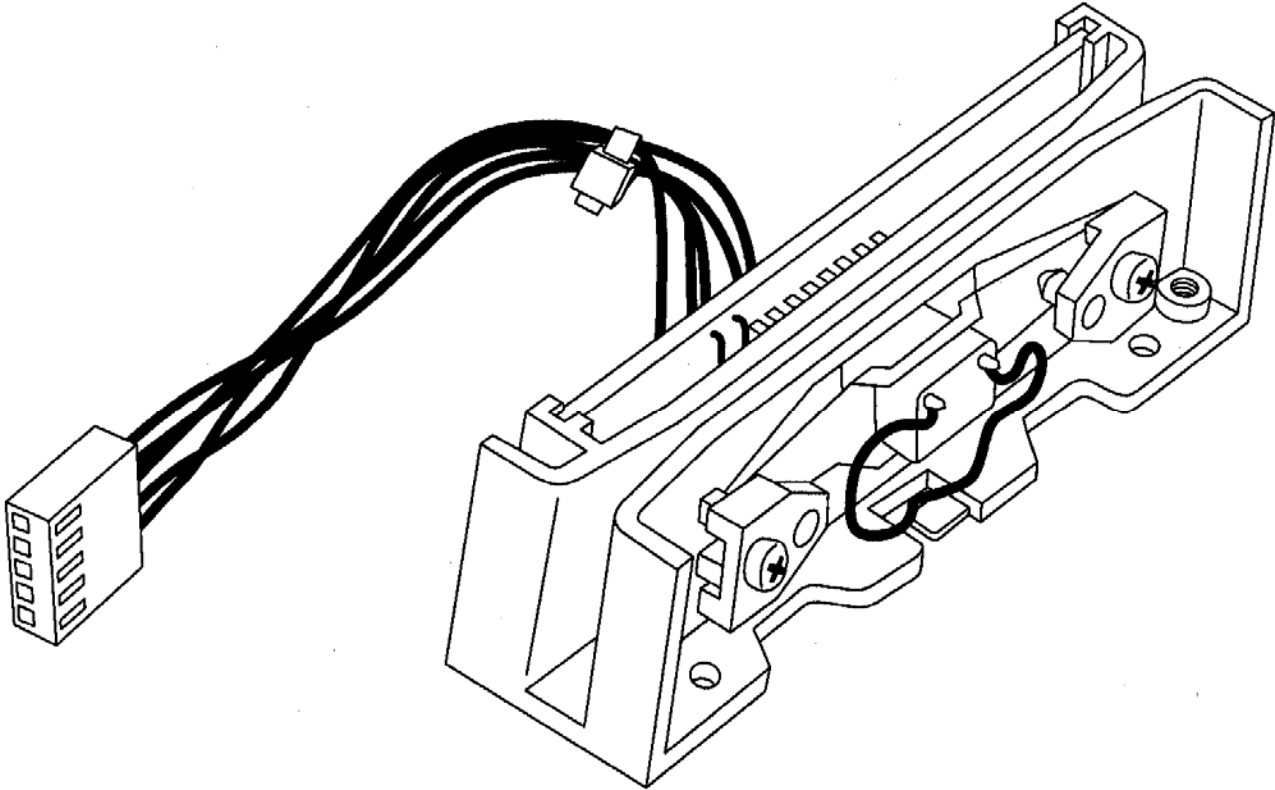
Magtek Magnetic Stripe Reader

Table 2-1. I/O Connector for Single Track, 5 Pin

	Pin Number	Color	Signal
Connector for Single Track, 5 Pin	1	Red	V_{cc}
Molex 5 Pin	2	Black	GND
22-01-2051	3	Orange	$\overline{\text{DATA}}$
0.100 inch Contact Spacing	4	Brown	$\overline{\text{STROBE}}$
Mates to Molex 22-05-2051	5	Green	$\overline{\text{CARD PRESENT}}$

Note: V_{cc} = 2.7 to 5.5 VDC

Mag-stripe Reader Timing

CARD PRESENT

DATA   0   0   0   0   1   1   1   0   0   0   0   0   1   1   0

STROBE

Bit Time

STROBE WIDTH APPROXIMATELY
25-50% OF BIT TIME
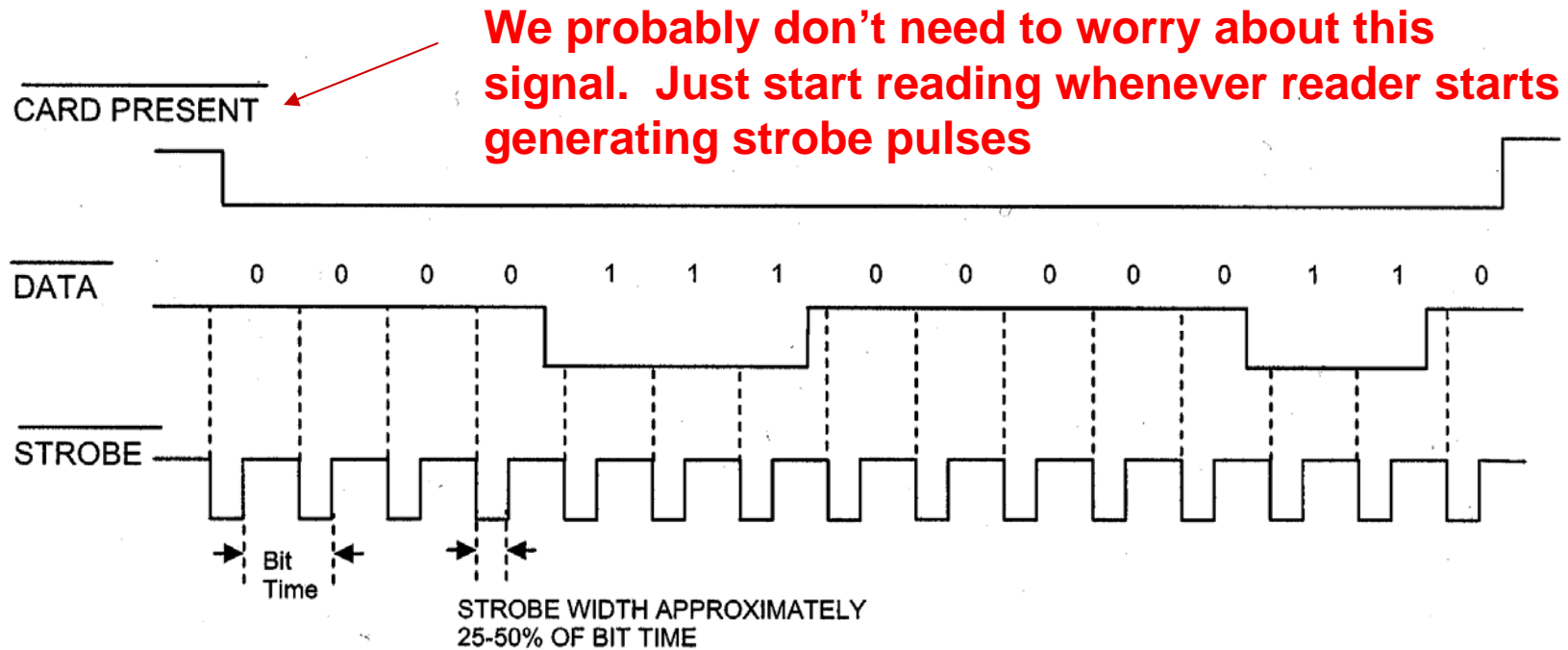
Notes:
1. Time out of the CARD PRESENT signal occurs approximately 150 ms after the last strobe transition.

2. DATA is valid 1.0µ sec before the negative edge of STROBE.

3. 16 or 17 head flux reversals for high density configuration.

Mag-stripe Reader Timing

We probably don't need to worry about this signal. Just start reading whenever reader starts generating strobe pulses

CARD PRESENT

DATA   0   0   0   0   1   1   1   0   0   0   0   0   1   1   0

STROBE

Bit
Time

STROBE WIDTH APPROXIMATELY
25-50% OF BIT TIME

Notes:
1. Time out of the CARD PRESENT signal occurs approximately 150 ms after the last strobe transition.
2. DATA is valid 1.0μ sec before the negative edge of STROBE.
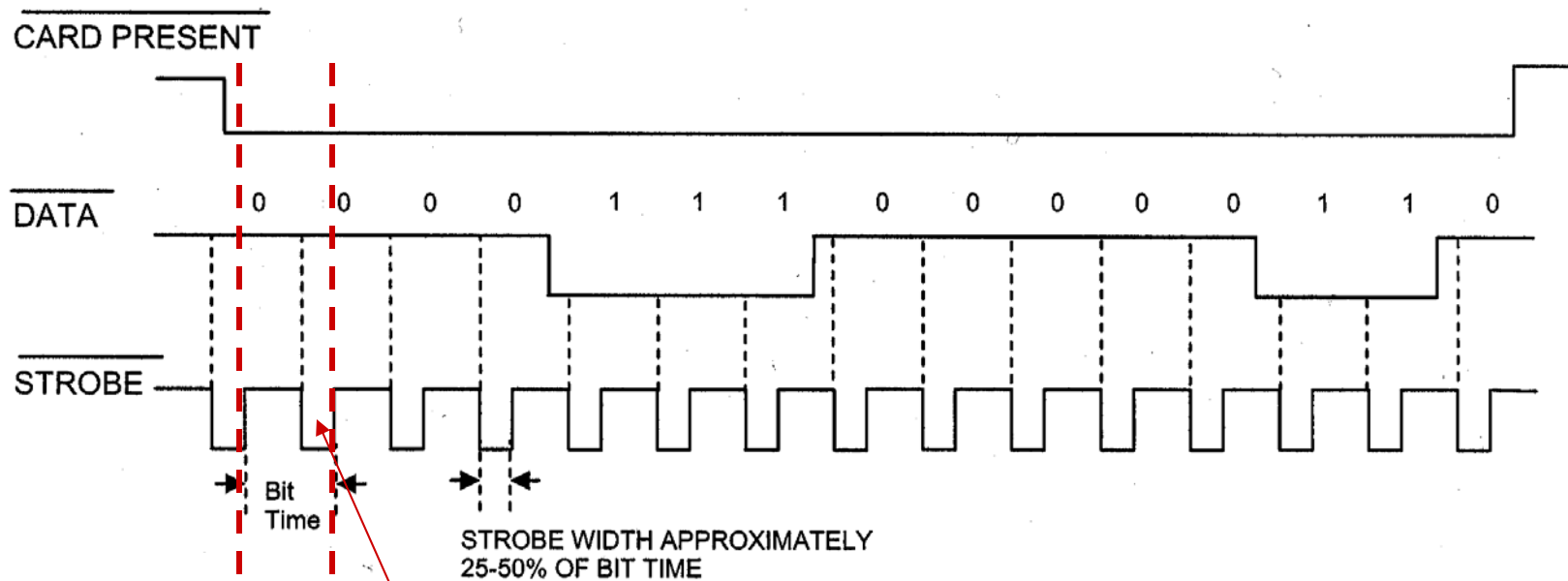3. 16 or 17 head flux reversals for high density configuration.

Mag-stripe Reader Timing

CARD PRESENT

DATA

| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |

STROBE
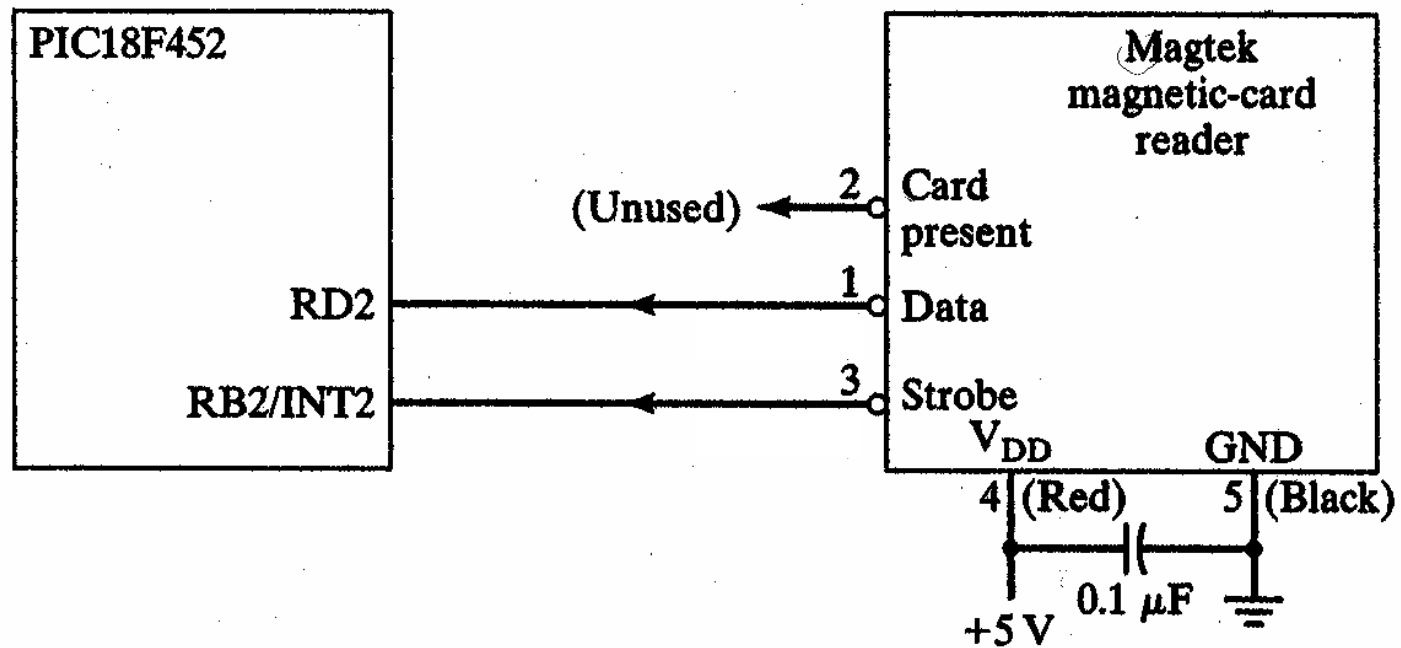
Bit
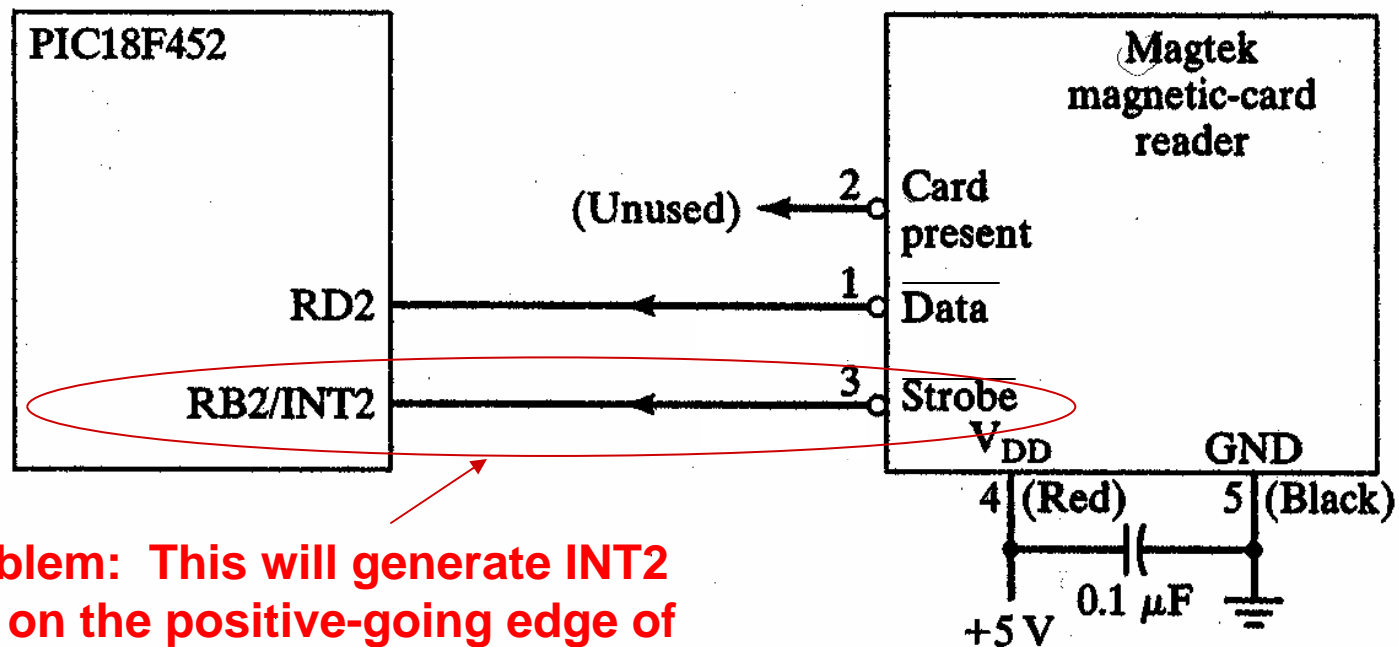Time

STROBE WIDTH APPROXIMATELY
25-50% OF BIT TIME

Notes:
1. Time out of the CARD PRESENT signal occurs approximately 150 ms after the last strobe transition.

2. DATA is valid 1.0μ sec before the negative edge of STROBE.

3. 16 or 17 head flux reversals for high density configuration.

Manufacturer recommends reading DATA on the negative-going edge of STROBE

Possible Interface of Magtek Reader to the PIC

Possible Interface of Magtek Reader to the PIC

PIC18F452

RD2

RB2/INT2

(Unused) ← 2 o Card present

1 o $\overline{\text{Data}}$

3 o $\overline{\text{Strobe}}$

Magtek magnetic-card reader

V_{DD} GND

4 (Red)   5 (Black)

0.1 μF

+5 V

Minor Problem: This will generate INT2 interrupts on the positive-going edge of $\overline{\text{STROBE}}$, while the manufacturer recommends reading data at the negative-going edge
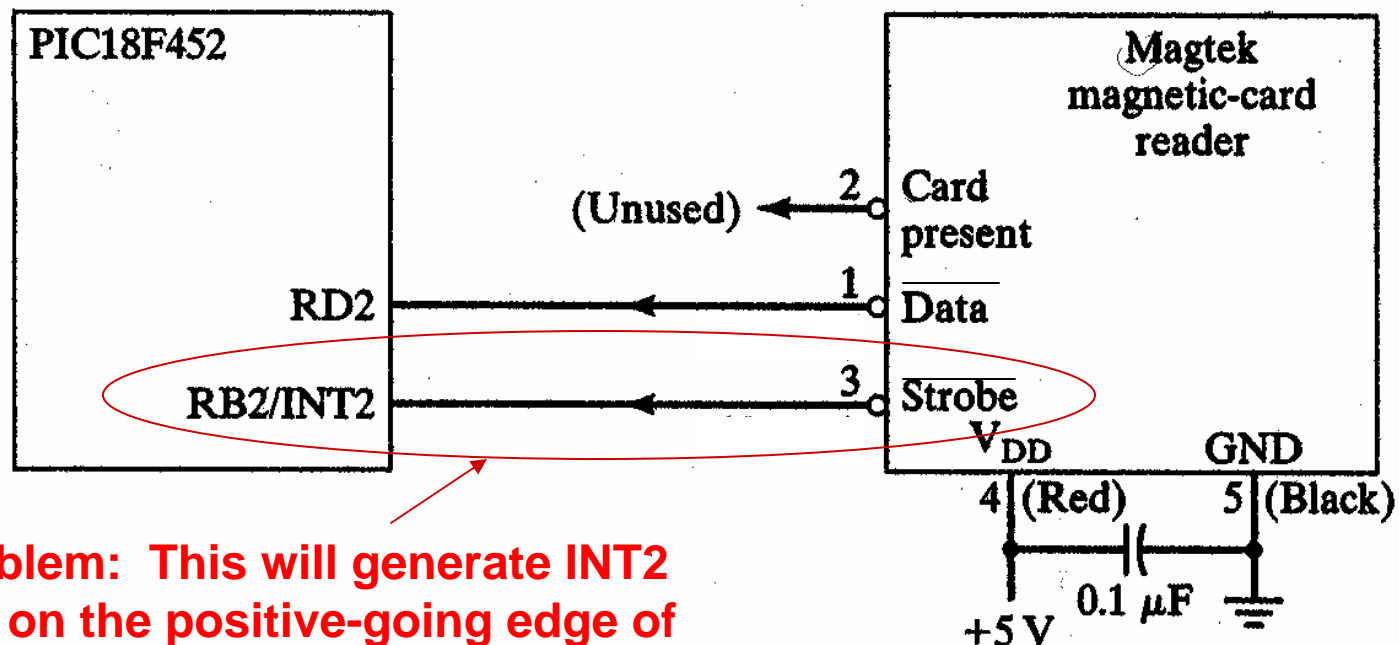
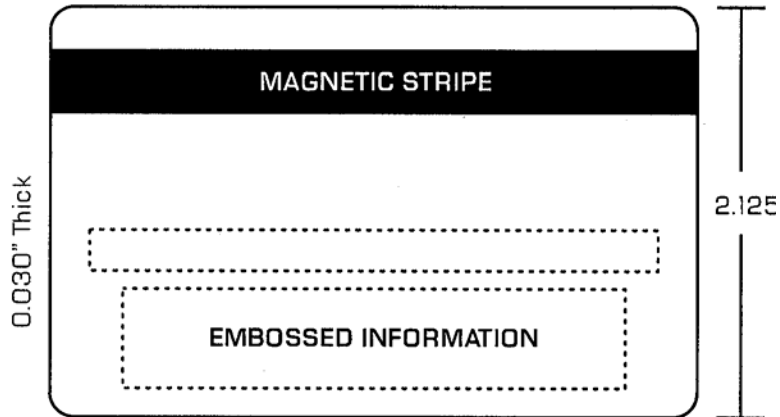# Possible Interface of Magtek Reader to the PIC

Minor Problem: This will generate INT2 interrupts on the positive-going edge of STROBE, while the manufacturer recommends reading data at the negative-going edge

Possible solutions:
1) Should be able to get away with reading on positive edge
2) If necessary, insert an inverter in the Strobe output

Mag-stripe format (ISO/ANSI 7811)

Dimensions - Financial Transaction Cards

Magnetic Stripe Encoding - Financial Transaction Cards

0.223"	Track		Recording Density (bits per inch)	Character Configuration (including parity bit)	Information Content (including control characters)
0.110"	1	IATA	210	7 bits per character	79 alphanumeric characters
0.110"	2	ABA	75	5 bits per character	40 numeric characters
0.110"	3	THRIFT	210	5 bits per character	107 numeric characters

Mag-stripe format (ISO/ANSI 7811)

Dimensions - Financial Transaction Cards

MAGNETIC STRIPE

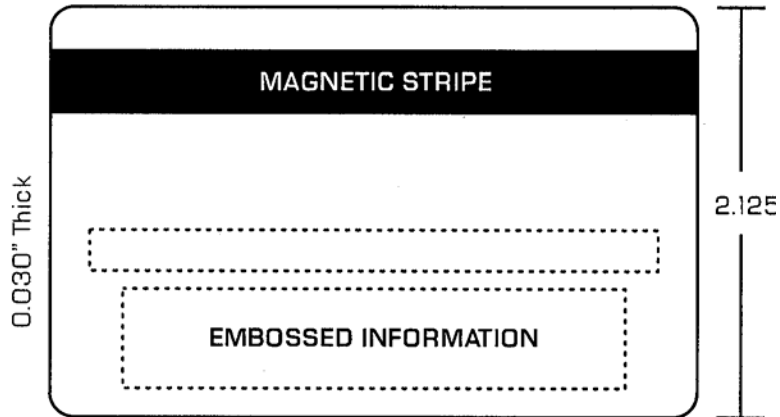0.030" Thick

EMBOSSED INFORMATION

2.125

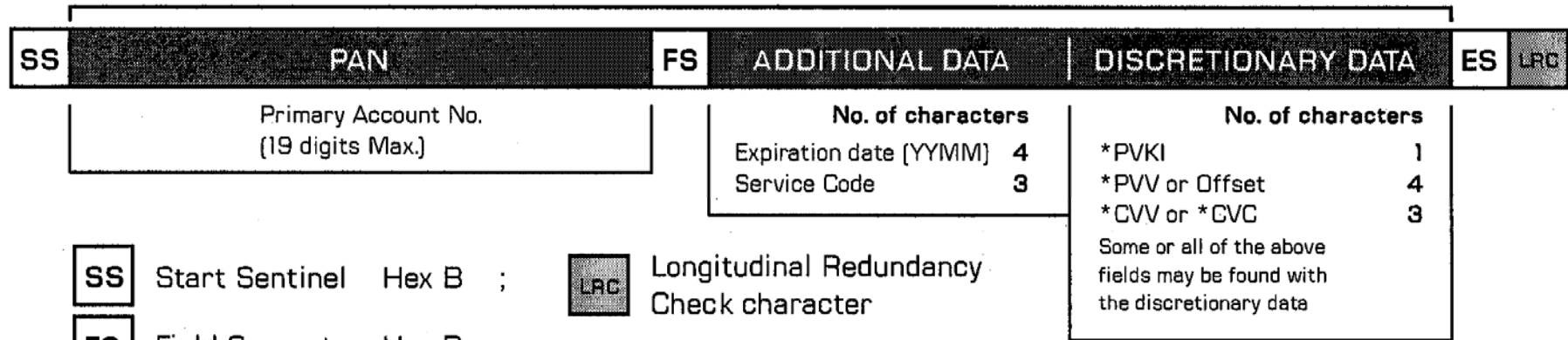**Magnetic Stripe Encoding - Financial Transaction Cards**

0.223"	Track		Recording Density (bits per inch)	Character Configuration (including parity bit)	Information Content (including control characters)
0.110"	1	IATA	210	7 bits per character	79 alphanumeric characters
0.110"	2	ABA	75	5 bits per character	40 numeric characters
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Our Magtek reader only reads track 2

Track 2 Format

Card Data Format - Track 2

37 NUMERIC DATA CHARACTERS

| SS | PAN | FS | ADDITIONAL DATA | DISCRETIONARY DATA | ES | LRC |

Primary Account No. (19 digits Max.)

No. of characters

Expiration date (YYMM) 4
Service Code 3

No. of characters

*PVKI 1
*PVV or Offset 4
*CVV or *CVC 3

Some or all of the above fields may be found with the discretionary data

SS Start Sentinel Hex B ;
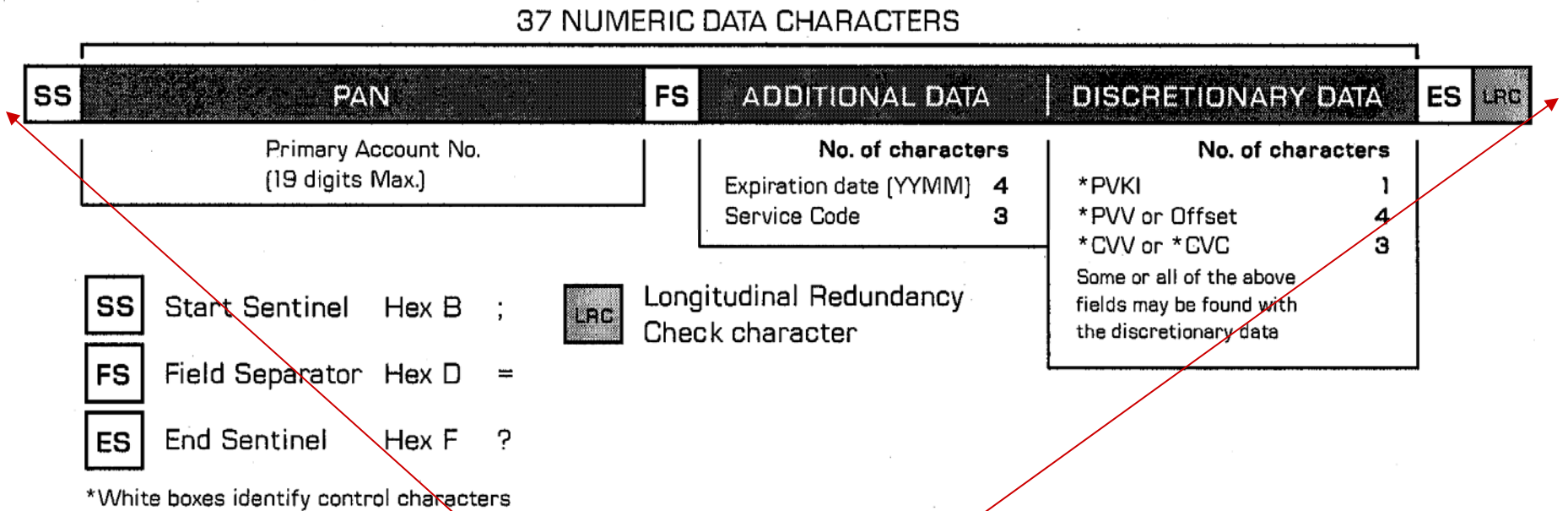
FS Field Separator Hex D =

ES End Sentinel Hex F ?

LRC Longitudinal Redundancy Check character

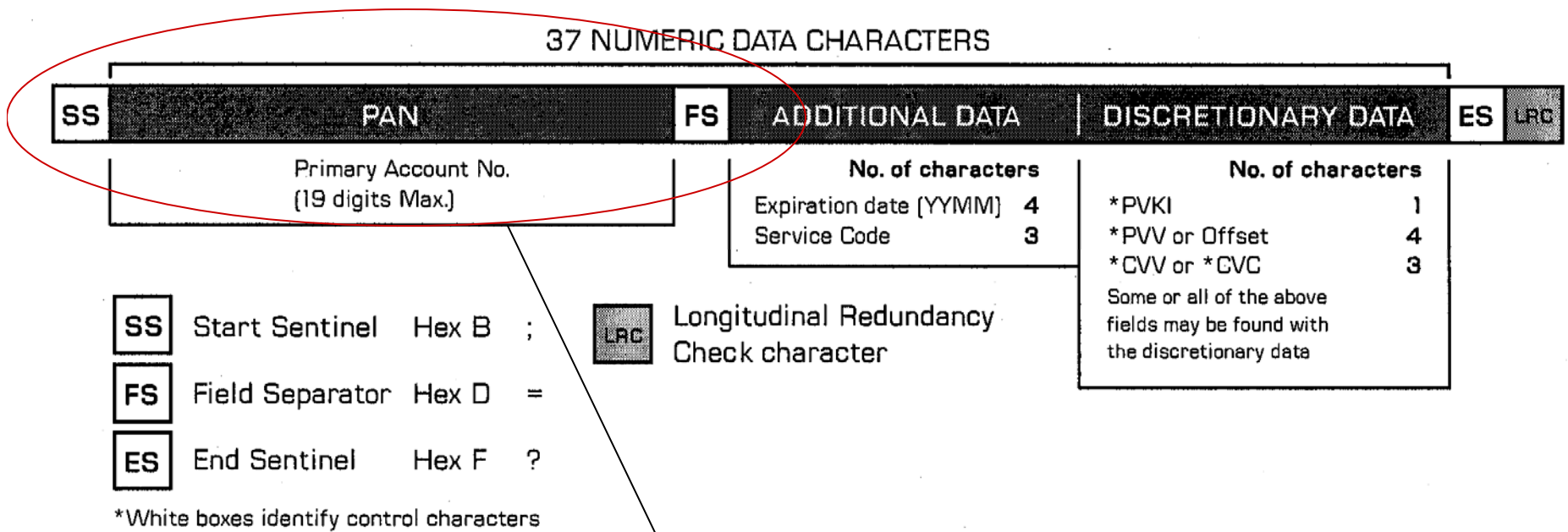*White boxes identify control characters

Track 2 Format

Card Data Format - Track 2

37 NUMERIC DATA CHARACTERS

| SS | PAN | FS | ADDITIONAL DATA | DISCRETIONARY DATA | ES | LRC |

Primary Account No.
(19 digits Max.)

No. of characters
Expiration date [YYMM] 4
Service Code 3

No. of characters
*PVKI 1
*PVV or Offset 4
*CVV or *CVC 3
Some or all of the above fields may be found with the discretionary data

SS Start Sentinel Hex B ;

FS Field Separator Hex D =

ES End Sentinel Hex F ?

LRC Longitudinal Redundancy Check character

*White boxes identify control characters

Data will be framed on both ends by strings of zero bits

Track 2 Format

Card Data Format - Track 2

37 NUMERIC DATA CHARACTERS

| SS | PAN | FS | ADDITIONAL DATA | DISCRETIONARY DATA | ES | LRC |

Primary Account No.
(19 digits Max.)

	No. of characters
Expiration date (YYMM)	4
Service Code	3

	No. of characters
*PVKI	1
*PVV or Offset	4
*CVV or *CVC	3

Some or all of the above fields may be found with the discretionary data

| SS | Start Sentinel | Hex B | ; |

| LRC | Longitudinal Redundancy Check character |

| FS | Field Separator | Hex D | = |

| ES | End Sentinel | Hex F | ? |

*White boxes identify control characters

We will use only this part

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 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

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

Remember, the data output from the stripe reader is inverted. Logical zeros will be read as high values, logical ones as low.

Mag-Card Reader—Concluding Comments

- Mag-stripe reader is discussed in Section 16.2 of the text
- Author's timing picture differs from Magtek Data sheet
  - Author shows middle of data-bit coincident with leading edge of STROBE
  - Data sheet recommends reading data on negative-going edge of STROBE
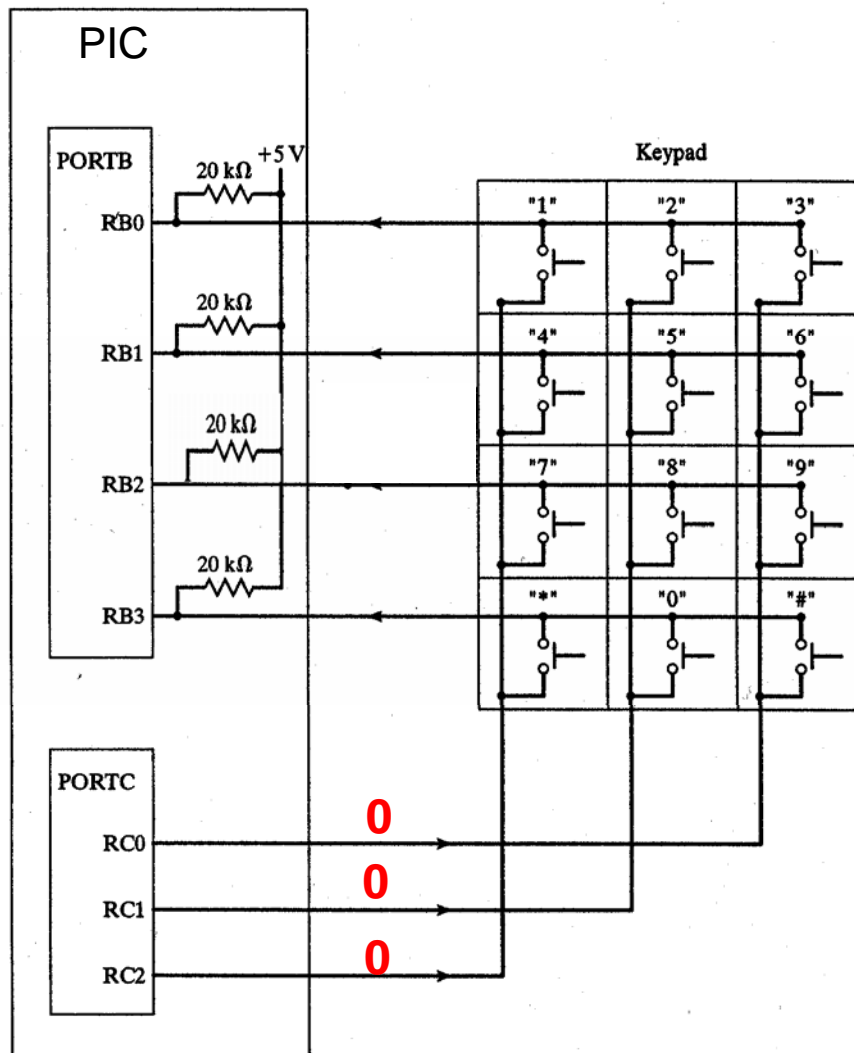- May have to experiment to see which works better
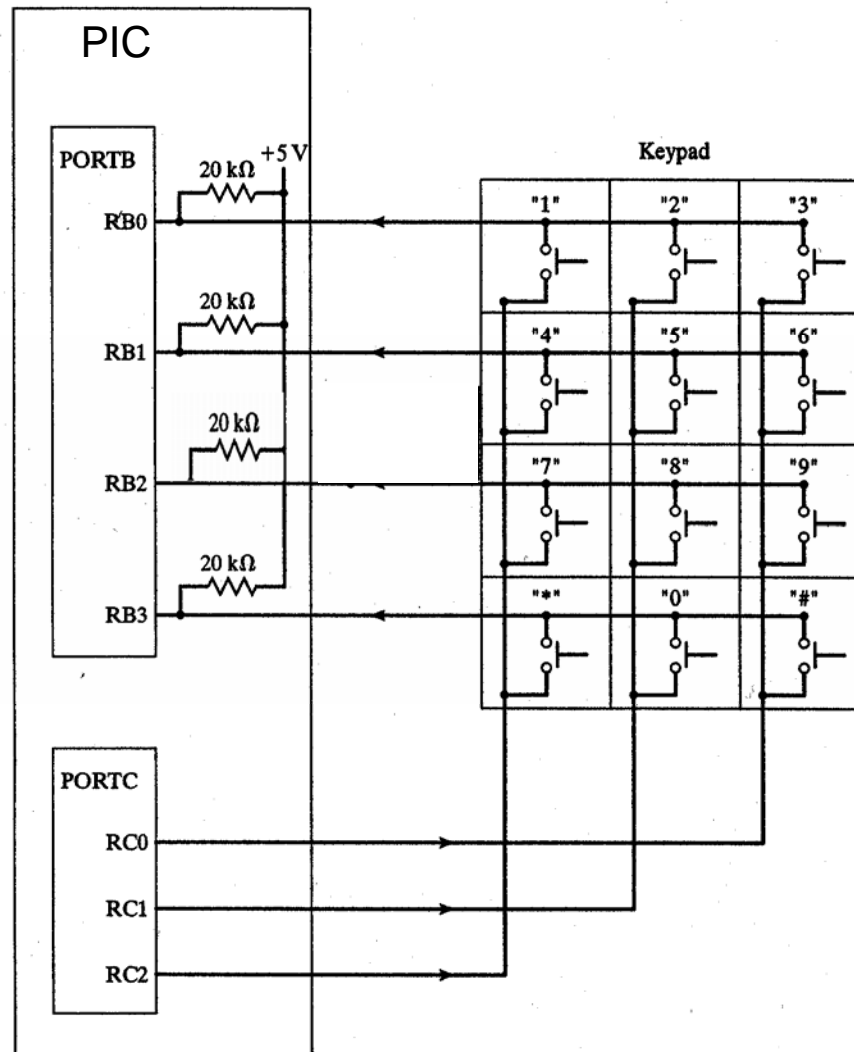
Reading a Simple (3 x 4) Keypad
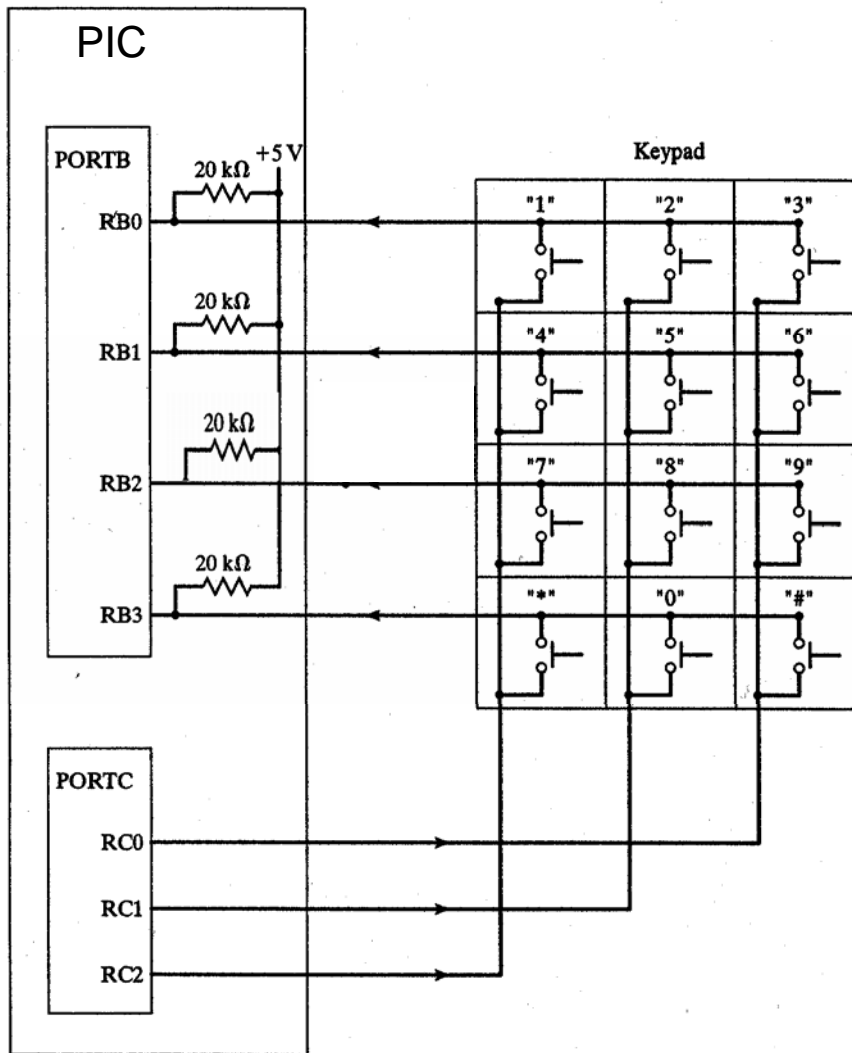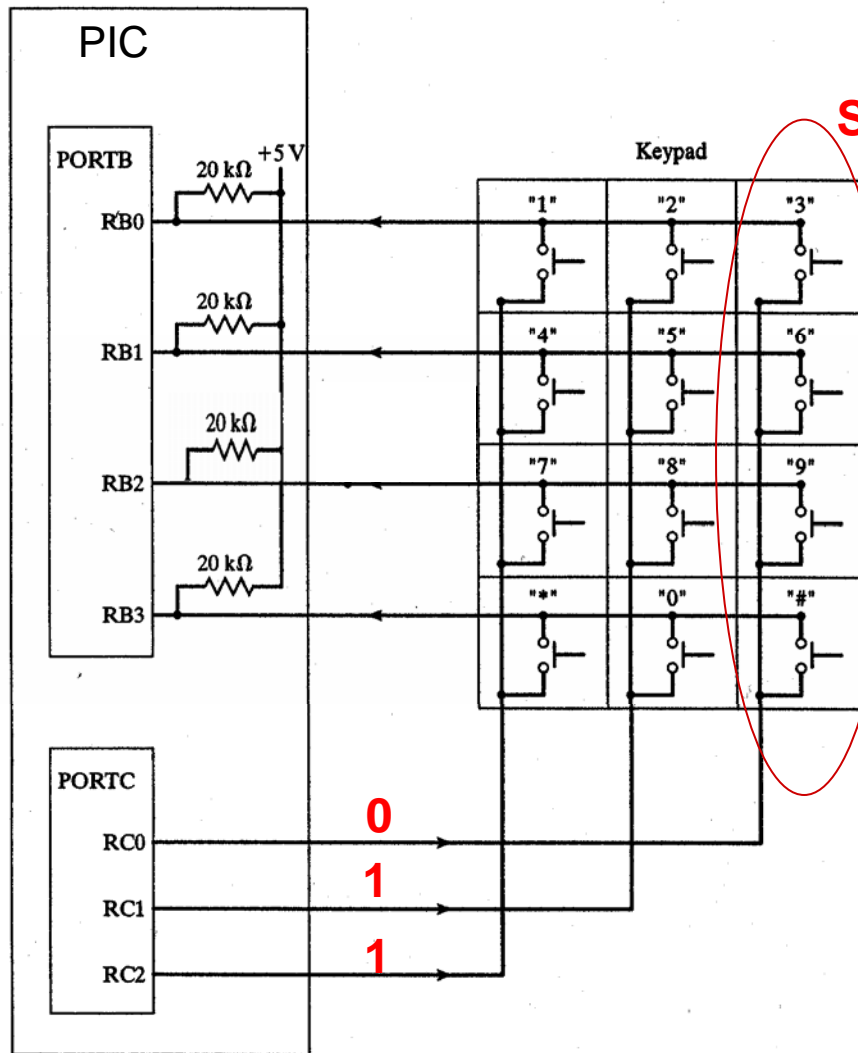
Reading a Simple (3 x 4) Keypad

Note the weak pull-ups on RB0-RB3. These must be enabled
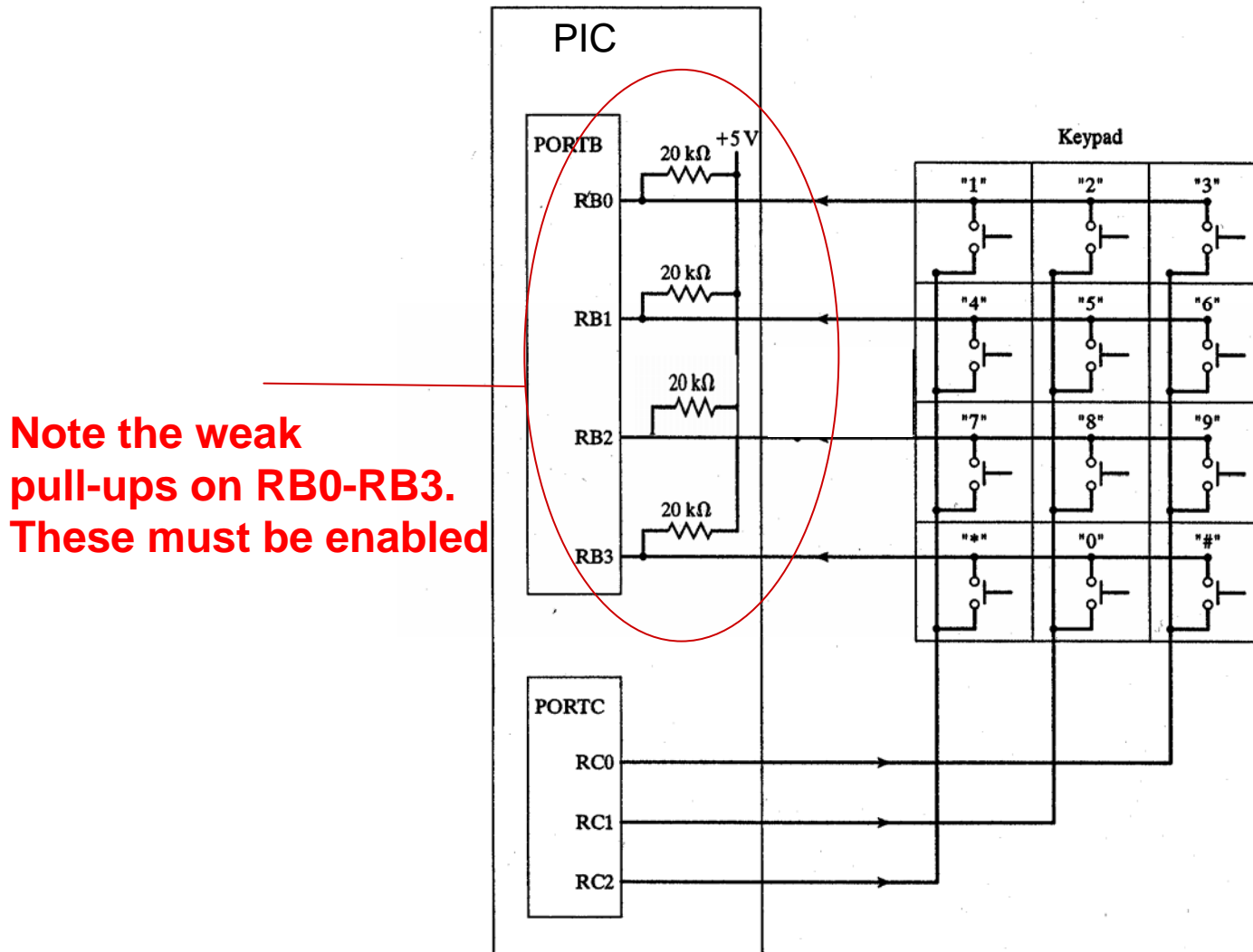
Reading a Simple (3 x 4) Keypad

Step 1: Detecting a Key press
   a) Drive RC0, RC1 RC2 low.
   b) READ Port B and look for zero on any of RB0-RB3
   c) If so, a key has been pressed

Reading a Simple (3 x 4) Keypad

Step 2: Debounce
   **Wait an appropriate period
   for the key switch to stabilize
   (10 msec is probably a good
   waiting time)**

Reading a Simple (3 x 4) Keypad

Step 3: Find the pressed key
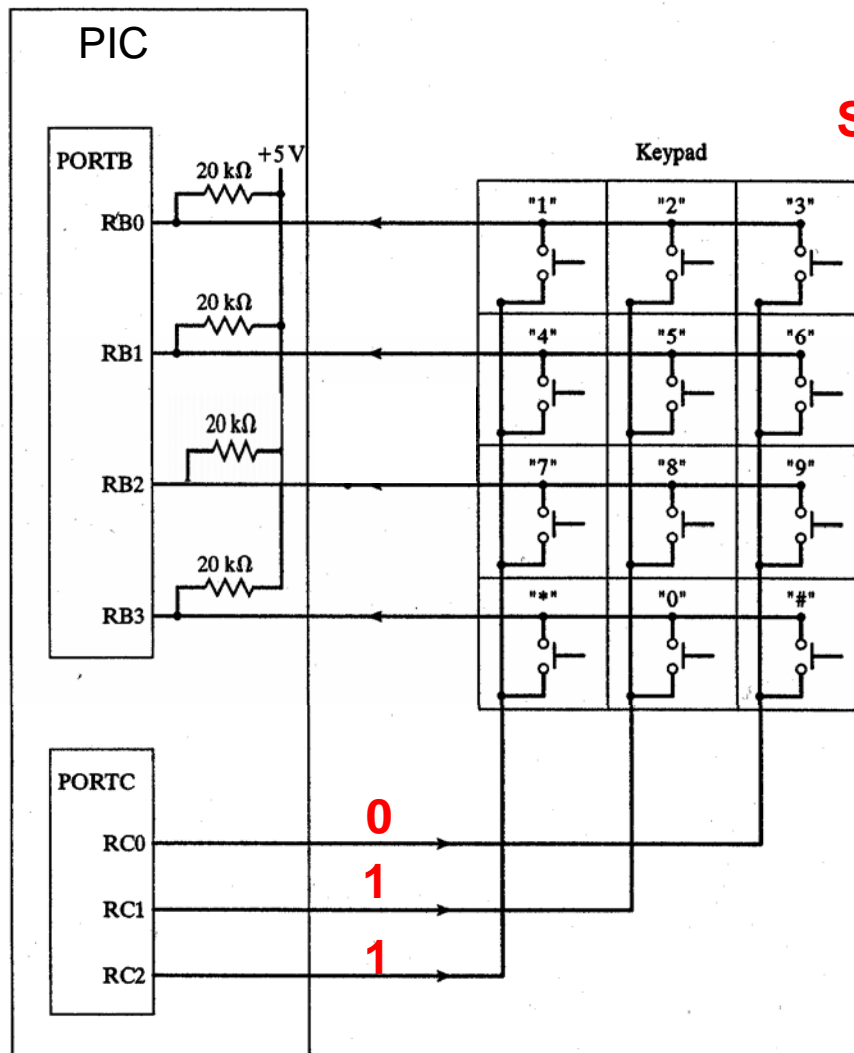   a) Drive RC0 Low, RC1-RC High
    b) Read Port B
        RB0 = 0 ➔ 3 pressed
        RB1 = 0 ➔ 6 pressed
        RB2 = 0 ➔ 9 pressed
        RB3 = 0 ➔ # pressed

Reading a Simple (3 x 4) Keypad

Step 3: Find the pressed key
    a) Drive RC0 Low, RC1-RC High
    b) Read Port B
        RB0 = 0 ➔ 3 pressed
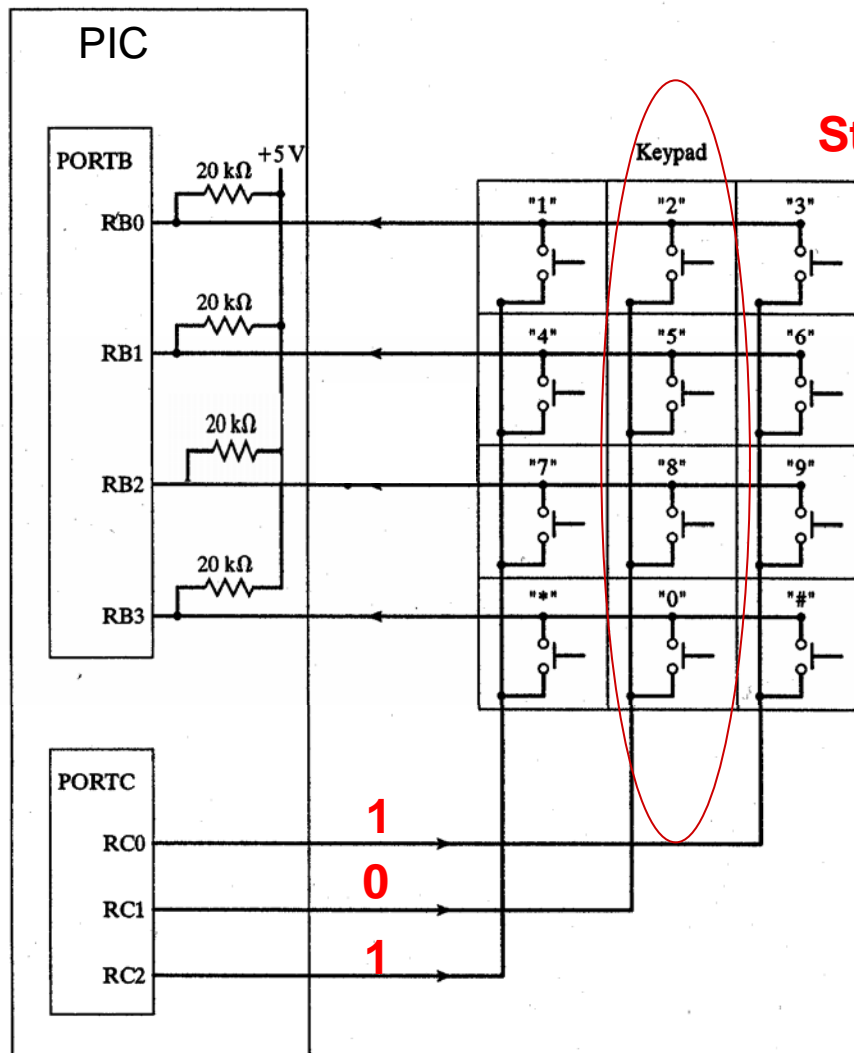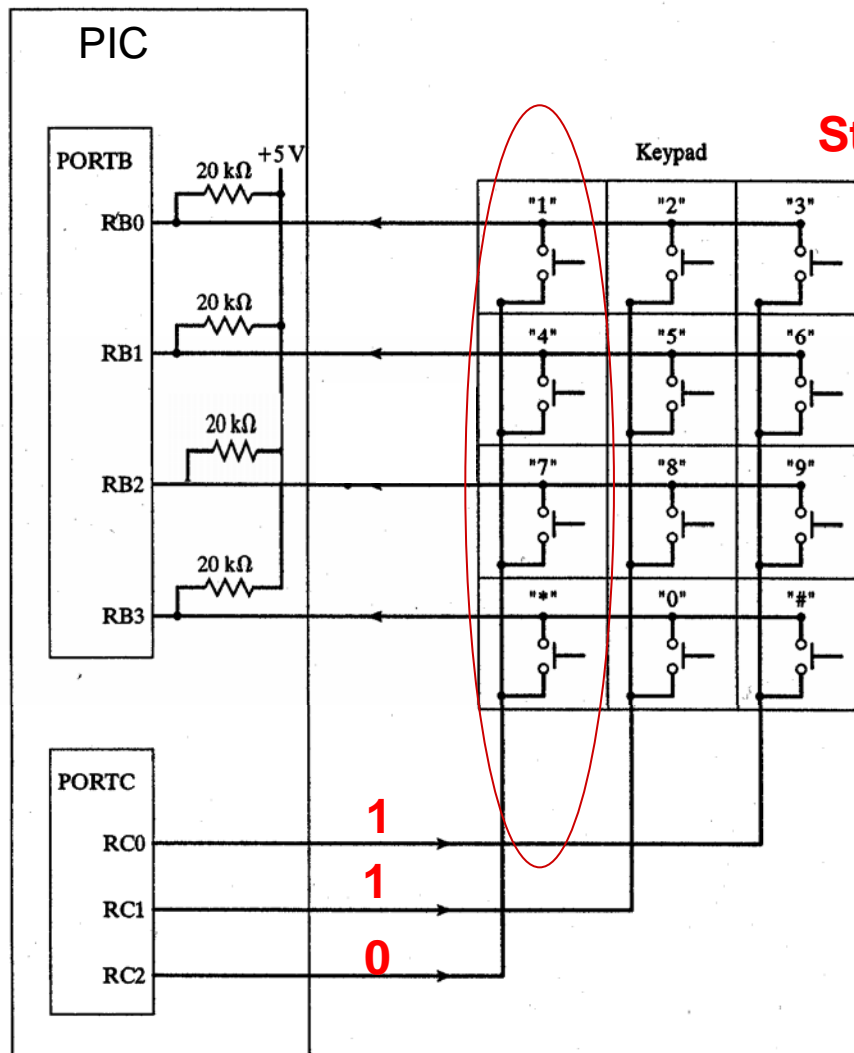   RB1 = 0 ➔ 6 pressed
        RB2 = 0 ➔ 9 pressed
        RB3 = 0 ➔ # pressed
   c) If pressed key is not found
      in column 3, repeat the
      process as necessary for the
      other two columns

Reading a Simple (3 x 4) Keypad

Step 3: Find the pressed key
  a) Drive RC0 Low, RC1-RC High
  b) Read Port B
      RB0 = 0 ➔ 2 pressed
      RB1 = 0 ➔ 5 pressed
      RB2 = 0 ➔ 8 pressed
      RB3 = 0 ➔ 0 pressed
  c) If pressed key is not found in column 3, repeat the process as necessary for the other two columns

Reading a Simple (3 x 4) Keypad

Step 3: Find the pressed key
   a) Drive RC0 Low, RC1-RC High
   b) Read Port B
      RB0 = 0 → 1 pressed
      RB1 = 0 → 4 pressed
      RB2 = 0 → 7 pressed
      RB3 = 0 → * pressed
   c) If pressed key is not found in column 3, repeat the process as necessary for the other two columns

Reading a Keypad—Concluding Comments

- Keypad reading is discussed in Chapter 19 of the text
- Note that both the Mag-stripe reader example and keypad example in these notes use pin RB2.
  - You will need to do some pin reassignments to use both devices at once
  - If you use pins on ports other than PORTB for keyboard **inputs** you will need to use external weak pull-up resistors.

Using the Data EEPROM

- PIC 18F452 has 256 bytes of data EEPROM
- Allows retention of data through processor power-down
- EEPROM is accessed via several SFRs
  - See Section 6 in the PIC18FXX2 data sheet for details
- Unlike the Program Memory (Flash), the Data EEPROM can be written to a byte at a time
- However, the write cycle time is VERY slow (approx 4 msec.)