Jonathan W. Valvano    April 13, 2007, 1:00pm-1:50pm.

(15) Question 1. A 32k by 8 bit PROM is interfaced to a 6811 running at 2 MHz

RDA = Read Data Available (from the ROM timing diagram in the question)
= (↓/CE + ta, ↑/CE + tb)
= (↑E + [10ns, 15ns] + ta, ↓E + [10ns, 15ns] + tb)
= (↑E +[10ns, 15ns] + [100ns, 150ns], ↓E +[10ns, 15ns] + [15ns, 20ns])
= (250 +[10ns, 15ns] + [100ns, 150ns], 500 +[10ns, 15ns] + [15ns, 20ns])
= (250 + 15ns+ 150ns, 500 +10ns+ 15ns)
= (415ns, 525ns)

RDR= Read Data Required (from the 6811 timing diagram in the book)
= ( t1 - t4 - t17, t1 + t18) = ( 500 - 20 - 30 , 500 +10 ) = ( 450 , 510 )

(15) Question 2. CPOL=1, CPHA=0 means clock normally high, master data and slave data are both shifted out on rising edge of SCLK. There should be exactly 8 clock pulses of duration 1 μs.

![Timing Diagram]

(15) Question 3.  

<table>
<thead>
<tr>
<th>RAM</th>
<th>$4000-$47FF</th>
<th>0100, 0XXX, XXXX, XXXX</th>
<th>must choose A12</th>
</tr>
</thead>
<tbody>
<tr>
<td>YourDevice</td>
<td>$5000-$57FF</td>
<td>0101, 0XXX, XXXX, XXXX</td>
<td></td>
</tr>
<tr>
<td>ROM</td>
<td>$6000-$77FF</td>
<td>011X, XXXX, XXXX, XXXX</td>
<td>must choose A13</td>
</tr>
<tr>
<td>ROM</td>
<td>$C000-$FFF</td>
<td>11XX, XXXX, XXXX, XXXX</td>
<td>must choose A15</td>
</tr>
</tbody>
</table>

Select = not(A15)*not(A13)*A12

(55) Question 4. You will design a data acquisition system to measure distance.

Part a) The sampling rate should be at least twice the largest frequency component in the signal, according to the Nyquist Theorem. Any frequency greater than 2*499=998 Hz is ok. I choose 1000 Hz.

Part b) 5V/0.2=25, thus a gain of 25 is needed. A differential amplifier will be used because the input is differential. The output swings from 0 to +5V, so rail-to-rail electronics will be needed. We can solve this interface with an instrumentation amp, which has a good CMRR. For an Analog Devices AD623, the gain = 1+(100kΩ/Rg), so Rg is 4.17kΩ. For an AD627, the gain = 5+(200kΩ/Rg), so Rg is 10kΩ.
Part c) Range/precision is resolution. 10m/1024 is about 0.01 m.

Part d) I choose an unsigned decimal fixed-point number system with a resolution of 0.01 m. The conversion is linear, mapping 0 to 0, and 1023 to 1000. For example, if the distance is 5 m, the $V_{out}$ voltage will be 0.1V, the PAD5 voltage will be 2.5V, the ADC conversion will be 512, and the output of the function will be 500. Overflow is handled by promoting to 32-bits. Any of these equations is ok:

$\frac{(1000*data)}{1023}$
$\frac{(1000*data)}{1024}$
$\frac{(1000*data+512)}{1023}$
$\frac{(1000*data+512)}{1024}$
$\frac{(125*data)}{128}$
$\frac{(125*data+64)}{128}$

unsigned short Convert(unsigned short data){
    unsigned long distance;
    distance = (1000*data + 500)/1024;
    return (unsigned short) distance;
}

Part e) Write the entire program implements this real time data acquisition system.

```c
void main(void){
    unsigned short data; // ADC sample 0 to 1023
    unsigned short distance; // fixed point, units 0.01m
    PLL_Init(); // initializes the PLL, changing the E clock to 24 MHz
    ADC_Init(); // initializes the ADC
    Fifo_Init(); // initializes a first in first out queue
    SCI_Init(115200); // initializes the SCI at 115200 bits/sec
    TIOS |= 0x01; // channel 0 is output compare
    TSCR1 = 0x80; // activate timer
    TSCR2 = 0x00; // TCNT at 24MHz
    TIE |= 0x01; // arm channel 0
    TCO = TCNT+50; // interrupt right away
    asm cli // enable
    for(;;){
        while(Fifo_Get(&data) == -1); // removes a 16-bit data from fifo
        distance = Convert(data); // 0-1023 into 0-1000 (0.01m)
        SCI_OutChar(13); // sends a CR to the PC
        SCI_OutFix(distance); // sends a fixed-point data to the PC, 0.01
    }
}

} interrupt 8 void TCOhandler(void){ // executes at 1000 Hz
    unsigned short data; // ADC sample 0 to 1023
    TPLG1 = 0x01; // acknowledge OCO
    TCO = TCO+24000; // 1 ms
    data = ADC_In(0x85); // returns 10-bit sample from channel 5, 0 to 1023
    Fifo_Put(data); // saves a 16-bit data into fifo, returns -1 if full
}
```

**Fifo queue analysis.** If SCI_OutFix sends 6 characters, each sample requires 7 SCI transmissions. There are 10 bits in a SCI frame (start, data, stop.) At 115,200 bits/sec, the SCI data rate is 11,520 characters/sec. The consumer rate is 11,520/7 characters/sec * sample/character = 1645 samples/sec. The producer rate is 1000 samples/sec. In fact, the time to produce 1 sample and the time to consume one sample are both fixed, therefore the Fifo will always have either zero or one element.