Prelab 2 Solutions

Problem 1: The MAX233

a) How does the internal supply work according to the MAX23x data sheet?

From the Maxim data sheet describing the MAX233 we have the following description. The description applies specifically to the MAX232 which has external capacitors.

“Dual Charge-Pump Voltage Converter
The MAX220–MAX249 have two internal charge-pumps that convert +5V to ±10V (unloaded) for RS-232 driver operation. The first converter uses capacitor C1 to double the +5V input to +10V on C3 at the V+ output. The second converter uses capacitor C2 to invert +10V to -10V on C4 at the V- output.

A small amount of power may be drawn from the +10V (V+) and -10V (V-) outputs to power external circuitry (see the Typical Operating Characteristics section), except on the MAX225 and MAX245–MAX247, where these pins are not available. V+ and V- are not regulated, so the output voltage drops with increasing load current. Do not load V+ and V- to a point that violates the minimum ±5V EIA/TIA-232E driver output voltage when sourcing current from V+ and V- to external circuitry.”

b) What external connections (pin numbers) provide access to the +10 and -10 volt supplies?

Pin 14 provides +10V, pins 12 & 17 provide –10V.

c) What is the ASCII code for the character "a"?

The ASCII code for "a" is 61h = 01100001.

d) What is the ASCII code for the first letter of your family name (upper-case)?

My family name starts with M, so the ASCII code for B = 4Dh = 01001101

e) Sketch what you would expect to see with an oscilloscope connected to the serial transmit lead, TD if you were sending the character "a" at 9600 baud, 8 bits, no parity

At 9600 baud, each code-element occupies 1/9600 sec.

f) If a MAX233 Receiver was connected to the input in part (c), sketch the receiver output.

TD is the signal from the IEEE-232 transmitter on the PC. In the "idle" state it is a negative signal -15 < V_{TD} < -3 ....typically -10V. The receiver inverts the signal.

Problem 2: Optical Isolation of the Serial Interface
a) When TD1 is +10 volts, what is the current in...

   LED-ISO1a? 0 mA.
   LED-ISO1b? \frac{(10-1.2)}{1.8K} = 4.89 mA

   What is the state of transistor...
   ISO1a? non-conducting
   ISO1b? conducting

b) What is the voltage on...
   the collector of transistor ISO2b?: +10V
   on the emitter of transistor ISO2a?: -10V

c) If TD2 is -10 volts and DTR2 is +10 volts wrt SG2, what is RD1 wrt SG1? What happens if data causes TD2 to alternate between +10 and -10 volts?

   LED ISO2a is on and transistor ISO2a is conducting so RD1 goes to -10 volts

   Sketch an example.

   Using the figure from problem 2 the waveshape of both TD2 and RD1 would be the same but the amplitude would be +10 and -10 volts.

d) Explain, in words, how the optical isolator works.

   IEEE-232 signals alternate between positive and negative values operating LED's which illuminate transistors. The transistors conduct when the associated LED is lit. Signal power is supplied by capacitors which are charged by the transmit TD and status DTR signals associated with the receiving link. There is no metallic path between the communicating data systems.
Problem 3: Lighting an LED

Using first the DS5000 and then the buffer, design a circuits which will provide 1.5 mA of current causing the LED to light. Model the LED and the driving circuit with a Thevenin or Norton equivalent for each possible state.

Begin by modeling the LED as a voltage source and a resistance. I used the LED model shown below since the scale of the figure supplied with the problem didn't describe operation at 2 mA very well. A simple piecewise-linear model can be derived by connecting the two points in the I-V curve. It has an intercept of 1.09V and an inverse slope of \((1.2V - 1.1V)/(20mA - 2mA) = 5.5\Omega\). These are the values for the model.

There are many circuit topologies that solve the problem, but only one for each output will be discussed.

The buffer’s HIGH voltage can be anywhere above 3.9 V, while its LOW voltage will be below 0.33 V. In either case, 4 mA of current can be supplied in the appropriate direction. We’ll use the LOW condition to turn on the LED because the voltage varies much less. Using the circuit shown below, the only unknown is the resistor. To find out what it needs to be to limit the current to 1 mA, plug in the LED and buffer output circuit models. Using Ohms Law, the total resistance is found from \((5V – 1.09V – 0.33V) / (R + R_L + 5.5\Omega) = 1mA\). Thus, the needed resistance is around 3.58k\Omega. To be safe, we might choose \((5V – 1.09V)/1mA = 3.9k\Omega\).

Since the DS-5000 can only supply 80\mu A out of a port, we cannot use a port to just drive the LED. The circuit suggested below solves the problem. When the output is HIGH, there is a drop across the resistor and the 5V supply provides the current for the LED. When the output is LOW, the voltage across the diode is not enough to turn it on and the DS-5000 sinks the current from the resistor. To calculate the resistance, the common node must be \(1.1V + 5.5\Omega \cdot 1mA = 1.1 V\) when the LED is lit. The DS-5000 output can only supply 80\mu A, so the voltage supply provides the rest (essentially all the current). The resistor must then be \((5V – 1.1V)/1mA = 3.9k\Omega\) (or, accounting for the DS-5000 current, \((5V – 1.1V)/(1mA-0.08mA) = 4.24k\Omega\)). To check the OFF operation, the current the DS-5000 must sink is \(5V / 3.9k\Omega. = 1.28 mA\) (within spec).
**Problem 4: Lighting a Bank of LEDs**

a) Using a 74HCT14 and the DS5000, design a system which will illuminate a set of 4 light-emitting diodes.

The schematic is shown below. When a port goes HIGH, the inverter goes LOW and current flows through the diode. The resistor was chosen to get the 4mA current requirement. With a 5V supply and a 1V diode drop, we need 4mA over 4V: that’s a 1kΩ resistor. More precisely 5-1.1/4mA = 975Ω.

b) Specify DS5000 BASIC statement(s) which will operate the LED’s and explain what they do.

PORT2 = value will send data to PORT 2 and operate the LED’s. Since our four LED’s are in the least significant bits of PORT 2, these are the bits that control them. For example, the lowest LED is in P2.0. It will be lit whenever PORT2 is odd. To light it alone, use PORT2=1. To light the others, use PORT2=2, 4, or 8 to light P2.1, P2.2, P2.3 respectively.

c) The timing diagram below represents a sequential pattern of the LED’s.

We’ll now use this command to light the LED’s in the sequence shown above. To light in the sequence, we need to set PORT2 to 1, 2, 4, 8, 0 every second. One second in real time corresponds to approximately 300 cycles in a FOR-NEXT loop. Thus, PORT 2 will cycle through:

<table>
<thead>
<tr>
<th>Decimal</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>00000001</td>
</tr>
<tr>
<td>2</td>
<td>00000010</td>
</tr>
<tr>
<td>4</td>
<td>00000100</td>
</tr>
<tr>
<td>8</td>
<td>00001000</td>
</tr>
<tr>
<td>0</td>
<td>00000000</td>
</tr>
</tbody>
</table>

and so on.

The code could be:

```
10   PORT2=0       :REM Reset PORT2
20   W=1
30   FOR J=0 TO 4
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40 PORT2=W
50 FOR I=0 TO 150 :NEXT I :REM Pause for 0.5 second
55 PORT2=0 :REM TURN OFF LEDs
57 FOR I=0 TO 150 :NEXT I :REM Pause another 0.5 seconds
70 W=W*2.AND.0Fh :REM Move over 1 pin
80 NEXT J
90 GOTO 20

This will cycle through the pins and even produce the 1-second blank (that’s why we mask with 0Fh=00001111). I determined empirically (which is science-talk for I did an experiment) which showed that it took DS5000 BASIC could do about about 300 iterations of FOR NEXT in 1 sec.

Problem 5: Interfacing a Switch to the DS5000 Microprocessor

a) Design a circuit (with the DS5000) which will let the logic sense the state of the switch.

The figure shows an example of a simple input circuit which senses the logic state of a switch. It may have bouncing issues, but it would still work. The resistor is chosen to limit the current when the button is pushed. A 10-kΩ resistor would limit the current to 5V/10kΩ = 0.5mA.

b) Explain the operation of these circuits, including waveforms.

The Schmitt trigger has a hysteresis input-output characteristic. This means that the threshold for a low-high transition is different than a high-low transition: a pseudo-memory. We use a lowpass filter (capacitor and resistor) on the front end to eliminate quick spikes in the bouncing. The Schmitt trigger does the rest. Note that inversions are not accounted for in the figure.