

## Lab 4 - RS-232 and RS-422 Interface Circuits

Adapted from a lab by Bob Nicholson.

### Introduction

You will design, build and test an RS-232 interface circuit using the MAX232 line driver/receiver IC and compare its characteristics with the RS-232 specifications. Then you will design, build and test an RS-422 interface circuit using the MC3487 and MC3486 line driver and receiver ICs and compare their characteristics with the RS-422 specifications.

The component datasheets and the ITU-T V.28 (equivalent to RS-232) and V.11 (equivalent to RS-422) specifications are available on the course web site. We will use the ITU standards because they are freely available online while the EIA/TIA standards are not.

Due to the shortage of balanced line emulators you may be asked to do the two parts of the lab in reverse order.

### Pre-Lab

Prepare a pre-lab report including the diagrams and answers asked for in the following sections. Submit your report in PDF format to the appropriate dropbox on the course web site *before the start of the lab*.

You can create the sketches and schematics using a drawing or schematic capture program, by scanning a hand-drawn sketch or by taking a screen capture of an existing diagram.

Always identify the source of anything in your report not created by you. Copying material without mentioning the source is called *plagiarism* and can have serious consequences.

Instead of sketching scope waveforms you may take a photograph of the scope display. Record the image file name, the scope settings (time/division and voltage/division) and a description of the signal being measured. Crop and adjust the contrast and brightness if you include the photos in your report. You can also invert the colors. See Figure 1 for an example.

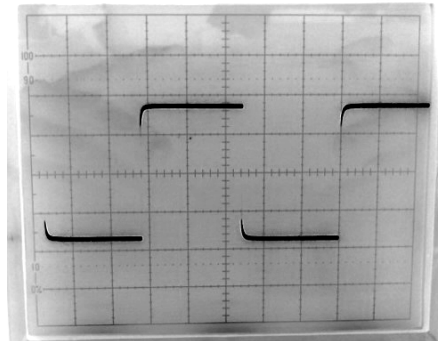


Figure 1: Sample oscilloscope photo with colors inverted. 5 V/div. 50 ms/div.

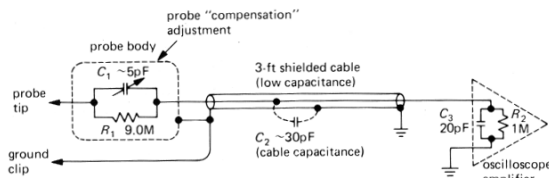
Note that specifications may be a minimum value, a maximum, both or neither. When asked for a specification below, include all that apply and identify the type (min or max).

### RS-232 Interfaces

1. Sketch or include a copy of the schematic diagram of an RS-232 interface circuit using a MAX232 integrated circuit. Include the four required charge-pump capacitors, including the polarity of the capacitors. The  $1\mu\text{F}$  bypass capacitor from  $V_{CC}$  to ground is optional. What does a charge pump do? How many does the MAX-232 have? Why? (Hint: read the datasheet.)
2. If the driver was being used for a handshaking signal, what logic level (H or L) would assert that signal (make it true)? If the driver was being used for a data signal what logic level (H or L) would be used to output a '1'?
3. What are the RS-232 (V.28) input and output impedance specifications? What are the MAX-232 specifications?
4. What are the RS-232 output slew rate specifications? What is the maximum load capacitance allowed by the specification? What are the

MAX232 slew rate specifications? Under what test conditions? What do you expect to happen to the output waveform as you increase the load capacitance?

5. What current is flowing into a capacitor of capacitance  $C$  if the voltage across it rises at a rate of  $S$  volts/second. (Hints:  $Q = CV$  and  $I = \frac{\Delta Q}{\Delta t}$ ).
6. The figure below<sup>1</sup> shows the equivalent circuit for the input of a scope and a 10x probe. What capacitive load does the probe represent when using a x1 probe (that is, just the cable)? The probes in the lab typically present a capacitive load of about 12pF when in the x10 mode. Why might you want to use a 10X probe to measure the (unloaded) slew rate of the line driver?



## RS-422 Interfaces

1. Sketch or include a copy the schematic diagram of an RS-422 interface circuit. Use one MC3487 and one MC3486 IC. Ensure that the tri-state controls on both chips are enabled (these are used for RS-485 applications).
2. What are the RS-422 logic level specifications? Why doesn't the MC3287 require a negative supply or charge pump?
3. If the bit period is  $1\mu s$  and the voltage swing is 4 volts, what is the minimum RS-422 slew rate? The minimum slew rate for the MC3487?
4. Why would you use a balanced transmission line when testing an RS-422 interface?

## Oscilloscope Measurement Techniques

### Differential Measurements

You can set up the scope to measure the difference between two voltages directly. This lets you measure

<sup>1</sup>From Horowitz and Hill's *The Art of Electronics*.

voltages across two parts of the circuit when neither one can be connected to ground.

Set up both input channels for the same gain (e.g. both calibrated and both set for 5V/division). Set one channel to invert (INV) its input. Set the display mode to "add" (instead of 1, 2, "alt" or "chop").

### Delayed-Trigger Measurements

You can set up the second timebase to run after a variable delay after the trigger. The second timebase is set to a faster sweep rate than the first time base. This allows you to "zoom in" on a portion of a waveform to make more accurate measurements.

Set the horizontal display mode to "intensify" (A INTEN). Increase the Timebase B sweep rate so that it is faster than Timebase A. Set the A timebase trigger to Channel 1. Set the B timebase trigger to "after delay". Adjust the intensity control so that you can see a highlighted portion of the trace. Adjust the Timebase B sweep rate and the delay control (a calibrated 10-turn potentiometer) to select the portion of the waveform you want to magnify. Change the horizontal display mode to "delayed". You will see a magnified portion of the waveform. The sweep rate within the magnified portion is set by Timebase B and the time offset from the start of the trace is determined by the delay control setting and Timebase A.

## Procedure

### RS-232 Interface

1. Build the MAX232 interface circuit leaving the output of the line driver and input to the receiver disconnected. Force the logic input to the line driver alternately H and L and measure (1) the MARK and SPACE voltages at the output of the driver. (2) Do they fall within RS-232 specifications?
2. Use a resistor (or a 10k or 20k pot) to measure (1) the output impedance of the line driver. (2) Does output impedance of the driver meet the RS-232 specification (if any)? The MAX232 specification?
3. Measure (1) the input impedance to the receiver using a potentiometer. (2) Does input

- impedance of the receiver meet the RS-232 specification? The MAX232 specification?
- Apply a 100 kbps (50kHz) 50% duty cycle TTL-level (0 to 5V) signal to the logic-level input of the driver using a function generator and measure (1) the slew-rate at the output using a 10x probe. (2) Does it meet the RS-232 specification? The MAX232 specification? Place a 330pF capacitor on the driver's output and again measure (3) the slew-rate. (4) Does this meet RS-232 specifications?
  - Using the measured slew rates, determine the current output/input by the driver.
  - Connect the output of the line driver to the input of the receiver (remember to remove any potentiometers used to measure output impedance or input impedance and any extra load capacitance) and again (1) measure the slew-rate. (2) Does the receiver have any appreciable capacitance? (3) How can you tell?
  - Connect an unbalanced transmission line emulator between the line driver and the receiver. Monitor the output of the receiver and adjust the frequency until the ratio of high to low is 1:3 (or vice-versa). Record this frequency as (1) the maximum frequency (half of the bit-rate).
- Set up the scope to measure the differential voltage across the two outputs (see instructions above). (1) Sketch the waveform.
  - Connect a balanced transmission line emulator between the line driver and receiver as shown in the diagram below. Connect the transmission line ground to the RS-422 driver and receiver ground. At the RS-422 receiver, connect a 120 ohm resistor between the differential inputs. Measure and record (1) the maximum bit-rate that you can achieve using the same criteria as above. (2) How does this bit rate compare to the bit rate that can be achieved with the RS-232 interface? (3) What specification limits the RS-232 data rate compared to the RS-422 data rate? (4) Why did the designers of the RS-232 interface choose to set this limit? (5) How could users of RS-422 circuits deal with this issue?



### RS-422 Interface

- Build the interface circuit, connecting the outputs from the MCS3487 to the inputs of the MC3486.
- Using a function generator, apply a 9600 bps TTL signal to the input of the MC3487. Connect channel two of your scope to the non-inverted output of the MC3487 and channel one to the inverted output. Ensure that both channel inputs are DC coupled and know where your ground references are for both channels.

Sketch (1) the waveforms you observe on channels one and two for two cycles of  $V_{in}$ . Measure and record (2) the MARK and SPACE voltages. (3) Do they fall within RS-422 specifications?

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### Lab Report

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Submit a lab report showing the measurements (voltages, currents, impedances, slew rates, waveforms, etc), and any calculations and answers to the questions asked in the procedure sections above.

Submit your report, in PDF format, to the appropriate dropbox on the course web site.