

## RS-232 Interface Circuit

Adapted from a lab by Bob Nicholson.

### Introduction

You will build and test an RS-232 interface circuit using the ICL-232<sup>1</sup> line driver/receiver IC and measure its input and output impedances and its output slew rate.

The ICL-232 datasheet is available on the course web site.

### 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, or by scanning or taking a photograph of a hand-drawn sketch.

Do not just copy-and-paste the schematic in the datasheet. The purpose of drawing *your own* schematic diagrams is to become familiar with the circuit.

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.

Note that specifications in the datasheet may be minimums, maximums, both or neither. For example there may be a minimum input impedance, a maximum or both. When asked for a specification in the questions below, include all that apply and identify the type (minimum or maximum).

Note that for baseband signals a transmitter is often called a line driver. In this document the terms line driver and transmitter are used interchangeably.

Note that in this lab you are measuring the characteristics of the transmitter and receiver independently. You won't connect one to the other.

<sup>1</sup>The manufacturer prefix for this IC varies but it is commonly referred to as a MAX-232 because it was popularized by the Maxim semiconductor manufacturer. You may be using either a MAX-232 or ICL-232 in the lab.

Use the ICL-232 datasheet from the course web site to answer the following questions.

1. Sketch the schematic diagram of an RS-232 interface circuit using the ICL-232 integrated circuit<sup>2,3</sup>. Include the four required charge-pump capacitors, noting the polarities of the capacitors. The  $1\mu\text{F}$  bypass capacitor from  $V_{CC}$  to ground is optional.

An IC that contains independent components (e.g. two drivers and two receivers) should show these as independent components, *not* as one block. These are typically labelled U1A, U1B, etc. Line drivers and receivers are typically drawn as triangles (similar to op-amps):



2. Read at least the first section of the “Detailed Description” section of the ICL-232 Datasheet. Understanding how the IC works will help you troubleshoot any problems. Answer the following questions:
  - (a) How many line drivers does this IC have? How many receivers?
  - (b) Assuming a 5V supply voltage for the interface IC and an interface driven by 5V TTL logic levels, what high and low voltages would you expect on the receiver inputs? On the receiver outputs? What voltages would you expect on the transmitter inputs? The transmitter outputs? Give your answer in the form of a table.

<sup>2</sup>The Functional Diagram schematic on page 2 is missing a connector dot. The capacitor connections are correctly shown in Figure 1.

<sup>3</sup>A schematic is not a parts layout diagram. The former uses symbols and lines to show electrical connectivity while the latter shows the positions and sizes of components.

- (c) How many charge pumps does the MAX/ICL-232 have?
  - (d) What are they used for?
  - (e) With reference to the charge pump schematic in Figure 5 of the ICL-232 data sheet, approximately what voltages would you expect to see across C3 and C4?
  - (f) What is the voltage (relative to ground) at the positive terminal of C1 when S1 and S3 are closed and S2 and S4 are open?
  - (g) When the switch positions are reversed?
3. If the driver (transmitter) was being used for a handshaking signal (e.g. CTS), what logic level (H or L) at the input would assert that signal (make it true)?
  4. If the driver (transmitter) was being used for a data signal (e.g. RxD) what logic level (H or L) would be used to output a '1'?
  5. What are the ICL-232 receiver input and transmitter output impedance (resistance) specifications?
  6. What are the ICL-232 slew rate specifications?
  7. Assuming the minimum slew rate, how long would it take for the signal to switch from -5 to +5 V? If this represents 10% of the bit period, what is the maximum bit rate?
  8. When you connect a 1 kΩ resistor to the output of a device the output voltage drops from 9 V (the open-circuit output voltage) to 3 V (the loaded voltage). What is the output impedance of the device?
  9. When you connect a 15 V power supply to the input of a device through a 1 kΩ resistor. The voltage at the input of the device is 10 V. What is the input impedance of the device?

## Procedure

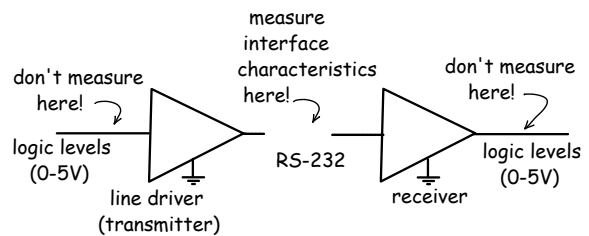
### Where to Measure

The function of a line driver (transmitter) and receiver are to interface logic levels to line levels. Thus

one side of each driver or receiver is a logic-level interface (e.g. TTL) and the other is a line-level interface (e.g. RS-232). Make sure you don't confuse the two interfaces. Your instructor will be very annoyed if you measure the input impedance of the transmitter or the output impedance of a receiver (you should understand why before coming to the lab).

The line drivers expect their inputs to be at TTL logic level voltages (0-5V). Set the AWG high and low levels to the correct values. Set the AWG for square-wave output.

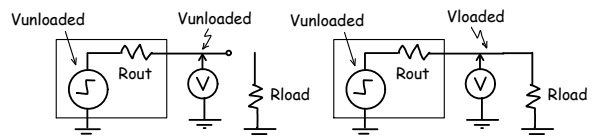
We want to measure specifications (impedance, slew rate, etc.) on the *line* side of the interfaces, not on the logic level side. Make sure you are measuring the right interface:



The ICL-232 includes two line drivers (transmitters) and two receivers. You can test either of the transmitters and either of the receivers.

### Measuring Input and Output Impedances

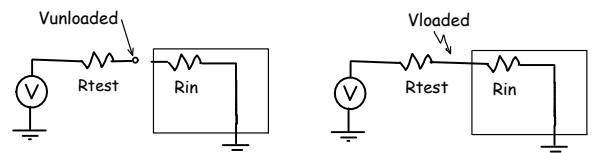
An output impedance can be calculated from the voltage ratio of the loaded and unloaded (open-circuit) output voltages:



The ratio of the two voltages is:

$$\frac{V_{loaded}}{V_{unloaded}} = \frac{R_{load}}{R_{out} + R_{load}}$$

The same procedure can be used to measure the input impedance except the voltage divider consists of a test resistor and the input resistance of the receiver:



However, note that the output voltage versus current characteristic may not be linear and so the apparent input and output impedances may depend on the current. You should make the measurements at the test conditions specified in the datasheet.

### Slew Rate Measurement

Press the Horizontal Scale knob to switch to the delayed timebase mode. In this mode you can “zoom in” on a portion of the waveform to allow more accurate measurements of, for example, the rising or falling edge of a waveform.

The slew rate is the slope of the steepest portion of the trace (voltage difference divided by time difference).

### Cautions

Note that the  $1\mu\text{F}$  capacitors are electrolytic and must be connected with the correct polarity (the striped side is negative).

Marks will be deducted for carelessness resulting in the destruction of components. Devices can be damaged by exceeding any of their “absolute maximum ratings” (e.g. reversed power supply polarity).

### Measurement Procedure

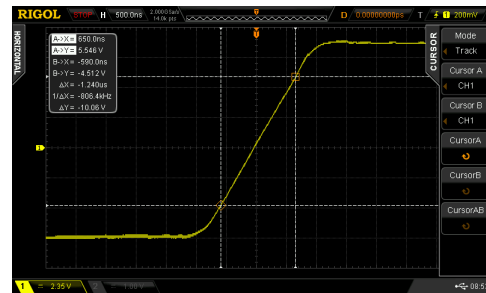
1. Build the ICL-232 interface circuit. Do not connect the line driver outputs to the receiver inputs – you will measure the line driver and receiver circuits separately.
2. Set up both 'scope channels for 10X input scale<sup>4</sup>
3. Set up the signal generator for a 50kHz (100 kbps) 0 to 5V (TTL-level) square-wave output; check the waveform on the 'scope<sup>5</sup>
4. Supply power to the interface circuit and then connect the signal generator output to the input of the *line driver*.
5. Measure the mark and space voltages at the input and output of the line driver. Take a screen capture showing the input and output signals.

<sup>4</sup>This is important; if you don't do this your measurements will be off by 10X.

<sup>5</sup>Warning: excessive or inverted input voltages will destroy the IC.

Do the output voltages meet the ICL-232 specification(s)?

6. Connect a resistor substitution box (“ $R_{load}$ ”) to the line driver output and adjust the load resistance to obtain approximately the test conditions listed in the Electrical Specifications Table entry for Output Resistance. Take a screen capture showing the line driver output. Calculate the line driver output current, voltage drop (compared to the unloaded output voltage) and from this the output impedance. Does the output impedance meet the ICL-232 specification(s)?
7. Set up the cursors in “tracking” mode to display  $\Delta X$  and  $\Delta Y$  values for the straight-line portion of the rising edge of the output (RS-232) waveform. For example:



8. Take a screen capture of the 'scope output showing the waveform and the measurements. Calculate the slew rate. Does it meet the ICL-232 specification(s)?
9. Connect the signal generator output to the input of the *receiver* through a resistor substitution box (“ $R_{test}$ ”). Adjust the signal generator output level to obtain the listed test conditions ( $V_{in}=3\text{V}$ ). From the voltage drop across the test resistance compute the current and the input impedance of the receiver. Does the input impedance meet the ICL-232 specification(s)?

### Lab Report

Submit a lab report with the usual identification information, your measurements (voltages, resistances, times, ...), screenshots, calculations, results

(impedances, slew rates), the relevant ICL-232 specification(s), and the answers to the questions in the procedure section above.

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