1 Prelab

NOTICE: In the past labs, we had a significant number of people come in without having finished the prelab. For the last lab, we will be much more strict about the prelab. Please get your prelab checked off on time. Prelabs checked off late will get either no credit (after lab session), or at best, half credit (not finished at the beginning of lab session).

1.1 Inverting Amplifier

Calculate the gain of this amplifier circuit:

![Inverting Amplifier Circuit](image)

1.2 Non-inverting Amplifier

Calculate the gain of this amplifier circuit:

![Non-inverting Amplifier Circuit](image)
1.3 Schmitt Trigger

For the purposes of this problem, assume all opamps saturate at ±15V, but are otherwise ideal.

You are designing the input stage to a digital circuit. You are trying to get the maximum possible bandwidth from the signal line you are using, and you found that as you begin to approach that limit, the signal line begins to act as a low-pass filter, so for this input:

You get this output:

You decide to clean up the signal by sticking in a comparator:
Sketch the output wave from the comparator on the above graph (be careful about signs). You plug in your circuit, and find that in addition to the low-pass properties of the signal line, there is some noise on top of your signal:

Again, sketch the output wave after the comparator on the above graph. What is the problem?

You pick up a copy of Horowitz and Hill, and find a circuit that uses a little bit of positive feedback to solve the problem:

Let’s say that the input is at 0V, and the output started at 1V. Figure out what the output goes to. What if the output started at -1V?
Now, find the switching thresholds of the circuit, with the output saturated to $+15\text{V}$ and $-15\text{V}$.

Now, again, sketch the output of this circuit, given the noisy input waveform:

1.4 Reading Assignment

Read the volt meter part of the lab and the ICL7129 spec sheet. Think about the circuit you will use build in this part of the lab. If you do not read these and plan out what you will do in advance, you will have a very difficult time finishing the lab within the scheduled time.
2 Lab

In this lab, we will only use the 356 op amp. The 356 is a good, cheap, easy-to-work-with op amp well suited to most basic circuits. More expensive op amps tend to sacrifice op amp ideality (finite input current, stability, power supply reject, etc.) for specific purposes (high speed, low noise, etc.) and can be much more difficult to work with.

The 356 pinout is the same as that of the 741, and is posted all over lab. For your convenience, we include a copy here:

![356 Pinout Diagram]

### 2.1 Amplifier

Build the amplifier circuit from the prelab:

![Amplifier Circuit Diagram]

Modify the component values in this circuit for a gain of 10. Show your changes on the schematic. Test your circuit. Is the gain what you expected?

Now, let’s assume we are trying to buffer a medium or high impedance load. Run the input through a 100kΩ resistor, and see how much the output changes.

### 2.2 Inverting Amplifier

Now, we will connect the inverting amplifier:
Modify the component values in this circuit for a gain of 10. Show your changes on the schematic. Test your circuit. Is the gain what you expected?

Now, let’s assume we are trying to buffer a medium or high impedance load. Again, run the input through a 100kΩ resistor, and see how the output changes. How does this compare to the non-inverting configuration?

2.3 Schmitt Trigger

Build the Schmitt trigger circuit from the prelab:

Measure at what voltages it switches. Does this meet your calculation from the prelab?


3 Volt Meter

In the last lab sessions of the class, we will use an integrated circuit (ICL7129) to built a simple voltage meter.

Note: The ICL7129 pdf file does not have very good resolution and some of the traces and connections in the example circuits are not very clear. For a more clear presentation you may look at the pdf file for the equivalent product TC7129 from microchip (www.microchip.com)

The main goals of this part of the lab are:

- To gain some experience in reading and interpreting data sheets.

- To realize that in the real world, with the large array of integrated multipurpose components that are available, the design of devices becomes a problem in systems integration and optimization.

- To become more familiar with putting together prototypes on the proto-board and with testing their performance.

3.1 Problem statement

Design and built a voltmeter based on the ICL7129A chip with the following characteristics:

<table>
<thead>
<tr>
<th>Input Voltage range:</th>
<th>$\pm 2\text{V}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage:</td>
<td>9 V</td>
</tr>
<tr>
<td>Accuracy:</td>
<td>1 mV</td>
</tr>
<tr>
<td>Resolution:</td>
<td>1 mV</td>
</tr>
</tbody>
</table>

We will be building the circuit presented on figure 1 of the 7129 data sheet.

A few things to remember:

1. Since we do not have an oscillator to drive our system we will be using a simple RC oscillator circuit in its place. The oscillator circuit we are going to be using is shown on Fig. 5B of the data sheet (Fig. 8 in the TC7129 data sheet). Note the implications that the use of the RC oscillator has on the resolution of the system. Question: What is the significance of the equation: $R = 0.45/(fC)$?

2. Pull the Range pin (37) HI (> 3 volts) for achieving the desired 2 Volt range.

3. For a reference diode you may use the voltage reference provided in your lab kit. Note the connection of this zener diode.

4. Pin 4 to pin 18 of the ICL7129 are outputs, which are used to connect to the LCD. The LCD is 1/3 multiplexed (3 commons) with the following pin to segment map: (See the data sheet for information on the descriptors used on the segment map)
<table>
<thead>
<tr>
<th>Pin</th>
<th>COM1</th>
<th>COM2</th>
<th>COM3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4F</td>
<td>4E</td>
<td>5DP</td>
</tr>
<tr>
<td>2</td>
<td>4A</td>
<td>4G</td>
<td>4D</td>
</tr>
<tr>
<td>3</td>
<td>4B</td>
<td>4C</td>
<td>B-C</td>
</tr>
<tr>
<td>4</td>
<td>3F</td>
<td>3E</td>
<td>4DP</td>
</tr>
<tr>
<td>5</td>
<td>3A</td>
<td>3G</td>
<td>3D</td>
</tr>
<tr>
<td>6</td>
<td>3B</td>
<td>3C</td>
<td>-    (negative sign)</td>
</tr>
<tr>
<td>7</td>
<td>2F</td>
<td>2E</td>
<td>3DP</td>
</tr>
<tr>
<td>8</td>
<td>2A</td>
<td>2G</td>
<td>2D</td>
</tr>
<tr>
<td>9</td>
<td>2B</td>
<td>2C</td>
<td>LOW BATTERY</td>
</tr>
<tr>
<td>10</td>
<td>1F</td>
<td>1E</td>
<td>2DP</td>
</tr>
<tr>
<td>11</td>
<td>1A</td>
<td>1G</td>
<td>1D</td>
</tr>
<tr>
<td>12</td>
<td>1B</td>
<td>1C</td>
<td>CONTINUITY</td>
</tr>
<tr>
<td>13</td>
<td>COM1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>-</td>
<td>COM2</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>-</td>
<td>-</td>
<td>COM3</td>
</tr>
</tbody>
</table>

### 3.2 Question on A/D resolution

What is the resolution of the A/D converter that is incorporated in the 7129? You should be able to answer this question by carefully reading the data sheet.

What is the purpose of the reference voltage?

What do you think happens if the reference voltage is not constant?

### 3.3 Test your circuit

Built the circuit and perform the following tests:

Use your 5 Volt power supply and design a variable input voltage source. (A simple voltage divider circuit with a variable resistor will do). Observe the input with your bench DVM and compare with the value displayed on the LCD of your voltmeter. Record your observations.
Check low battery operation:
When the supply voltage falls below some voltage the low battery indicator is activated. Perform a set of measurements to determine the actual low voltage threshold voltage value in your device. A simple voltage divider circuit with a variable resistor can be used for this experiment.