Interface Circuit Design with OP AMPs

By: John Getty
Laboratory Director
Engineering Department
University of Denver
Denver, CO

Purpose:

Practice circuit design using OP AMPs.

Equipment Required:

- 1 - Agilent 33401A Digital Multimeter
- 1 - Agilent E3631A Power Supply
- 1 - Protoboard

  Parts listed at the end of this lab (from Engineering Electronics Supply, Inc.)

Prelab:

Read Sections 3-5 and 4-4 through 4-8 in the text*, and this entire laboratory exercise.

Paraphrasing Sect. 3-5 of the text, “an interface circuit is a two-port network inserted at an interface to ensure that the source and the load interact in a prescribed way.” Figure 1 — and Fig. 3-28 in the text — provide a visual representation of the interface circuit concept. The design problems in this lab exercise ask you to design an active interface circuit.

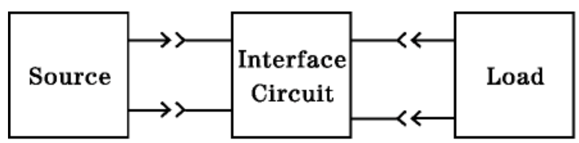

Figure 1

1. Select a partner

   Mutually select a lab partner. Determine your joint design project from Table 1, as follows. Add the last digit of your partner’s student number to the last digit of your student number. Your joint design project is determined by looking up the last digit of this sum in Table 1 below.

2. Design an interface circuit

   a. Meet with your partner before coming to the lab and create a workable design. If the design is not complete prior to the start of the lab session, you may not have time to build and adequately test the circuit.

   b. Analyze the design using a CCA program. If any problems are found because of this analysis, modify the design to correct them and rerun the analysis. Once you are satisfied with the design, print out the circuit and the results of the analysis, and tape them into your journal. Show the CCA results to a lab instructor before building the circuit in the lab.

   c. Prepare a parts list for the design, and add up the component cost to establish the cost of the design. Include the names and student numbers of all the members of the design team.

3. Design constraints

   a. Only the components listed in the “Parts Schedule” may be used in the design. The “Parts Schedule” is on the last page of this laboratory exercise.

   b. Make every effort to minimize the parts count, thus minimizing cost. Often cost is not the most important criteria used for judging the quality of a design. For example, low power consumption and high reliability are needed for space applications. However, reducing the parts count usually result in a lower cost design, and generally improves circuit reliability.

   c. Unless specified otherwise, the source signals are assumed to have a Thévenin equivalent resistance, $R_{TH} \leq 5\ \Omega$.

   d. Unless specified otherwise, the load circuit has an input resistance $R \approx \infty$.

   e. All specifications are ±5%.

   f. For circuit testing, your design team will need to devise a method of simulating the source circuit. However, do not add the cost of the source circuit to the final design costs.

   g. The load circuit for all design projects — except numbers 1 and 7 — is a DMM. The cost of the DMM will not be charged to the interface circuit design. For projects 1 and 7, the load circuit is an integral part of the design and is therefore chargeable to the final design costs.

Table 1

LAST DIGIT OF SUM	DESIGN PROJECT Design an ACTIVE Network that will:
0	A source circuit outputs two variable DC voltages, V_1 and V_2 . Design an interface circuit that is user-selectable to perform the functions $V_{out} = 2V_1 + V_2$ or $V_{out} = 3V_1 - 2V_2$.
1	Light a green LED when the source circuit voltage is greater than $3V_{DC}$, and light a red LED with the source voltage is less then $3V_{DC}$. Demonstrate the design can operate over the input range 0 to 5 V_{DC}.
2	Provide a switchable output of -1, -2, -4, -8, and -16 V_{DC} from a source circuit with a fixed 5 V_{DC} output.
3	Provide a general purpose instrumentation amplifier that performs the operation $V_{out} = m*V_{in} + b$, where m can vary from 2 to 10, and b varies from -12 V to +12 V.
4	Convert °C to °F over the range -5 to +5 °C. The source output ranges from -5 V_{DC} to +5 V_{DC} . Scale the interface output so °F = 10 V_{out} .
5	Convert °F to °C over the range 0 to 50 F. The source output is scaled from °F = 10 V_{in} or from 0 to 5 V_{DC} . Scale the interface output, °C = 10 V_{out} .
6	A source circuit has a variable Thévenin resistance, R_{TH} and an open-circuit output voltage V_S of -18 to +18 V_{DC} . Divide V_S by 2.0 and add +2.0 V_{DC} to it.
7	Convert an analog meter movement (check with the lab instructor for your particular meter) into a buffered voltmeter with three ranges; 100 mV_{DC} , 1 V_{DC} and 10 V_{DC} (full scale). Calibrate your meter using a digital voltmeter.
8	Provide a switchable output of +1, +3, +5, +7, +9 V_{DC} from a fixed +5 V_{DC} source.
9	Demonstrate a 4-bit, D-to-A converter. Use switches to simulate v_1, v_2, v_3 , and v_4 from the source, The maximum output, 1111_2 , must deliver 10 V_{DC} to the load circuit.

Procedure:

1. Construct the interface circuit

    a. Obtain the needed parts and build your circuit design. Remember that OP AMPs can be destroyed if they are wired incorrectly. Work on the prototype with the DC supplies turned off. To avoid wiring errors, double check the circuit.

    b. Construct the circuit in a modular fashion. In many cases, the design can be partitioned into several smaller sub-circuits. Troubleshooting the circuit is much faster if each sub-circuit is built and tested separately. Record the results of sub-circuit tests to help in the diagnosis of inadvertent "loading" problems that can occur when two circuit modules are connected together.

    c. Demonstrate the functioning prototype of your design to a lab instructor. Get a lab instructor's signature in your lab journal to verify that the design passed the critical design review and meets design specifications.

2. Record the data

    a. Record the pertinent performance data in your book. Review the design criteria to ensure that data has been collected to verify each condition of the design criteria. Where appropriate, make a plot of the performance data. Before disassembling the working prototype of your design, ensure that you have collected enough data to support the claim that the interface circuit meets the design criteria.

    b. More than one student pair may have the same design problem. The design team with the lowest project cost will be given a bonus grade on this lab exercise. To qualify for the competition, your design must earn at least a satisfactory grade. If no other team has the same design project, the bonus competition will be between you and the instructor.

    As in any design project, your write-up should fully document the *process* of design. As work on the project progresses . . . designing a circuit, verifying performance, and throwing out unsuccessful ideas, keep records on each design. Include the advantages and disadvantages of each circuit idea. These records should indicate the thought process that brought you to your final design.

Conclusion:

Create a table which summarizes the parts used in the final design. Include the parts cost, the total cost of the design, and the names of the members of the design team.

Any company, especially young start-ups, must effectively market their product. Typically, the advertising for electronic products is specific about feature and performance data, while incorporating all the common marketing tricks. Draw up a one page "spec-sheet/advertisement" for the promotion of your design. Be especially creative.

Engineering Electronic Supply, Inc.

PARTS SCHEDULE FOR "Interface Circuit Design with OP-AMPS"

Product	Price	Qty	Total
Switch, DPDT, Toggle	3.20		
Switch, SPST, Toggle	0.90		
Potentiometer, trimmer, 1/4W (Specify 1 k ohm, 10 k ohm, 100 k ohm)	1.50		
LM741 OP AMP	1.30		
Power Supply, 5 V	18.00		
Power Supply, 12 V, Dual Independent	24.00		
Power Supply, triple, variable	99.00		
Switch, 4-Pole DIP	0.90		
Meter movement, 1 mA full scale	6.00		
Potentiometer, 1/4W (Specify 1 k ohm, 10 k ohm, 100 k ohm)	2.30		
Photodetector	2.15		
Thermometer, alcohol	8.50		
LED (Specify red, green or yellow)	0.15		
A/D converter, 8-bit	6.95		
Resistor, Fixed 1/4W, all standard values	0.06		

- Immediate delivery with one stop shopping convenience.
- All products fully guaranteed, except for operator error.
- Design consultation service available ($160 per hour).
- Refunds and exchanges are cheerfully provided.

* Roland E. Thomas and Albert J. Rosa, The Analysis and Design of Linear Circuts, Prentice Hall, (New Jersey, 1994)