Sekolah Pendidikan Profesional dan Pendidikan Berterusan (SPACE)

JABATAN KEJURUTERAAN ELEKTRIK
PUSAT PENGAJIAN DIPLOMA (PPD), SPACE
UNIVERSITI TEKNOLOGI MALAYSIA
KUALA LUMPUR

DDWB/E/K 3711

(ELECTRONICS 2)

EXPERIMENT 3

OPERATIONAL AMPLIFIER

EXPERIMENT 1 : Bipolar Junction Transistor (BJT) and Field Effect Transistor (FET) : AC Analysis

OBJECTIVES

1. Examine the properties of the operational amplifier and learn to design practical op-amp circuits.
2. Verify the concepts and equations of the inverting and non-inverting amplifiers.
3. Investigate the use of the operational amplifier as a comparator.

COMPONENT/EQUIPMENT

1. Breadboard / Digital Trainer Kit
2. Three Resistors:R1=20 kΩ , R2=100 kΩ ,R3=20 kΩ, 390 Ω, 100 kΩ potentiometer, 8 Ω speaker.
3. Operational Amplifier: 741 (UA 741 LC)
4. DC Power Supplies with time-constant EMF (0 to 20.0V DC).
5. Digital Multimeter (DMM)
6. Function Generator
7. Oscilloscope

PROCEDURES

Part A : Inverting Configuration

1. Measure the resistances R_1, R_2 and R3 using DMM. Record the values in Table 1. Test the resistance of the potentiometer using DMM. Connect the circuit shown in Figure 1 using a 741 Op Amp. Be sure to connect the $\pm V_{CC} = \pm 15V$ supply voltages.
2. Verify that the gain is -5 (by calculation).
3. Adjust the function generator to 1V(p-p), 10 kHz. sine wave. Verify using oscilloscope.
4. Measure and record the output voltage in Table 1. Calculate the gain and compare with the theoretical gain in procedure 2.

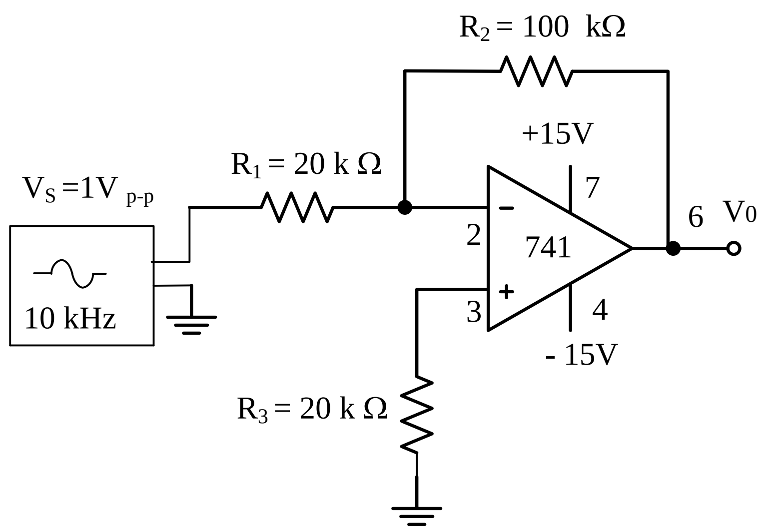


Figure 1

5. Confirm that the op-amp inverts the input by displaying both input and output on the scope (using CH 1 at the input and CH2 at the output). Sketch waveforms.

6. Increase the input amplitude of the function generator until the top of the output sine wave is being cut off. This effect is called clipping. Measure the voltage of the positive and negative halves. How do these values compared to ±Vcc?

Part B: Non-Inverting Configuration

1. Determine the gain of the circuit in Figure 2.
2. Connect the circuit in Figure 2.
3. Adjust the function generator to 1V(p-p), 10 kHz sine wave. Verify using oscilloscope.
4. Measure the output voltage, calculate the gain and compare with the theoretical gain in 1. Record in Table 3.
5. Using the oscilloscope, display both input and output waveforms. (Using CH 1 at the input and CH 2 at the output). Sketch and label the input and output waveforms.
6. Turn off the power supply .

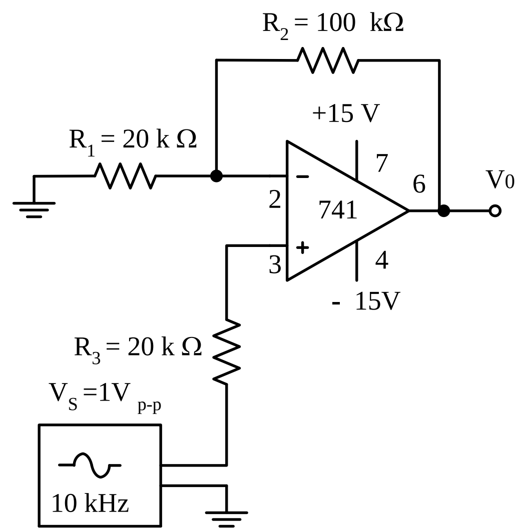


Figure 2

7. Modify the circuit in Figure 2 as in Figure 3. Use 20kΩ as R_1 and 100 kΩ potentiometer as R_2 and a speaker as the output
8. Turn on the function generator. Adjust the generator to 500mV peak to peak and the frequency to 100Hz.
9. Turn on the power supply(±15V).
10. Increase or decrease the amplification level using the potentiometer (R_2).
11. Using the function generator's frequency control, try different values of frequency. What is the minimum frequency you can hear? What is the maximum? Note down their values in Table 4.

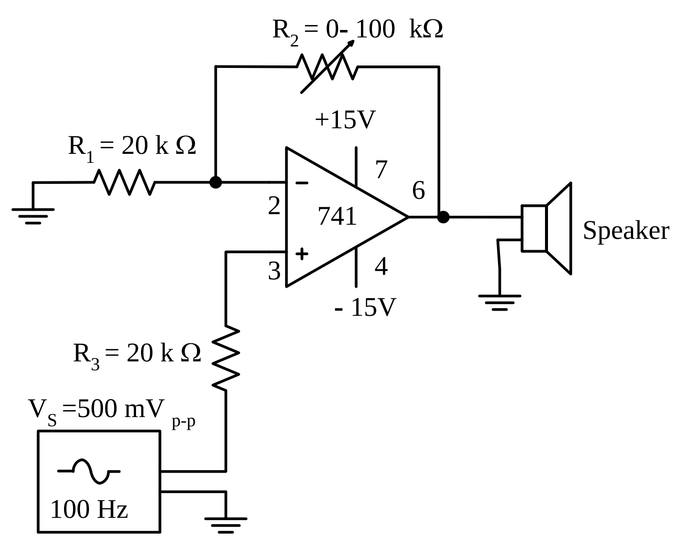


Figure 3

Part C: Comparator

(i) Simple Comparator with dc input

1. Wire up the op-amp and pot as shown in Figure 4.

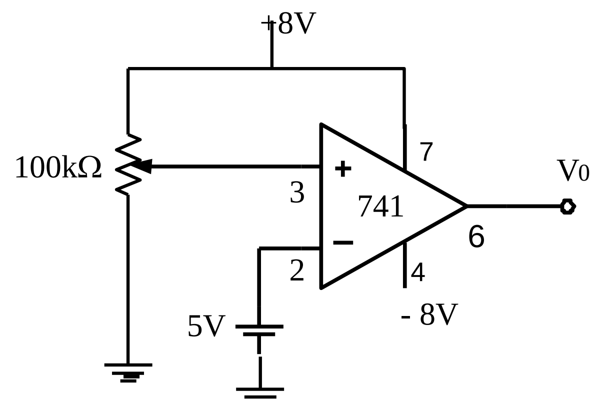


Figure 4

2. Vary the pot until v+ at pin 3 is 5.5v. Measure and record Vout at pin 6 in Table 6 .
3. Vary the pot until v+ at pin 3 is 4.5v. Measure and record Vout at pin 6.
4. The readings you get are the maximum and minimum saturation values of the op-amp for an 8V supply. Saturation values for most op-amps are 1 volt away from the supply volts.
5. Modify the circuit by adding a 390 Ω resistor and an LED at the output as in Figure 5.
6. Monitor the two voltage points v+ and Vout at the same time and observe the LED.

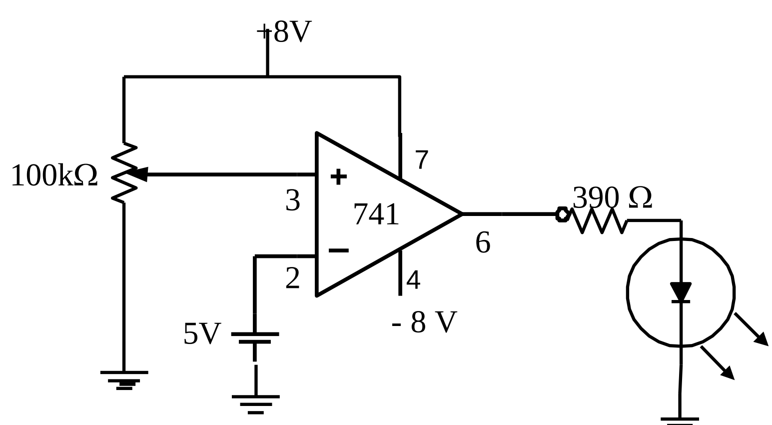
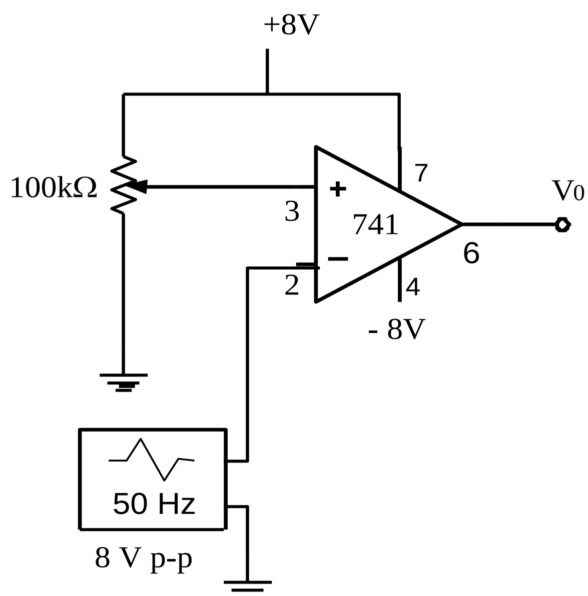


Figure 5

7. First, get an accurate reading of v- by using DVM to measure the voltage at pin 2 of the op-amp where the 5 volt supply is connected. For this measurement and the following two measurements, jot down all the digits displayed by the meter.
8. Vary the 100 kΩ pot carefully to get the minimum voltage needed at v+ (pin 3) to keep the voltage output at pin 6 at postive saturation or LED glowing. Record this voltage, (v+1).
9. The maximum voltage needed at v+ (pin 3) to keep the voltage output at pin 6 negative or LED dark. Record this voltage, (v+2). What is the difference (v+1 – v+2) ?
10. Switch off the power supply.

(ii) Comparator with triangular input waveform

1. Disconnect the the resistance and LED at the output as in Figure 6. Replace the supply voltage at pin 2 with a signal generator.



2. Set the voltage supply at v- (pin 2)to a triangular wave with a 8 V_{P-P} and frequency of 500 Hz .
3. Vary 100 kΩ pot to set voltage at V+ (pin 3) to 2 volts .
4. Use the oscilloscope to view the input and output voltages (CH 1- Vin and CH 2- Vo).
5. Sketch the input and output voltages shown on the oscilloscope on the same axis. Make sure the oscilloscope is at DC coupling.

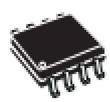
UA741

General-purpose single operational amplifier

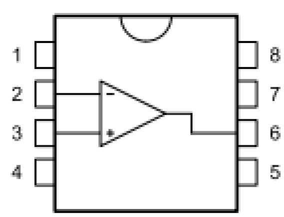
Datasheet - production data

N
DIP8
(plastic package)

D
SO8
(plastic micropackage)



Pin connections
(top view)



1 - Offset null 1
2 - Inverting input
3 - Non-inverting input
4 - V_{CC}^-
5 - Offset null 2
6 - Output
7 - V_{CC}^+
8 - N.C.

Features

- Large input voltage range
- No latch-up
- High gain
- Short-circuit protection
- No frequency compensation required
- Same pin configuration as the UA709

Applications

- Summing amplifiers
- Voltage followers
- Integrators
- Active filters
- Function generators

Description

The UA741 is a high performance monolithic operational amplifier constructed on a single silicon chip. It is intended for a wide range of analog applications.

The high gain and wide range of operating voltages provide superior performances in integrators, summing amplifiers and general feedback applications. The internal compensation network (6 dB/octave) ensures stability in closed-loop circuits.

2 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	±22	V
V_{id}	Differential input voltage	±30	
V_i	Input voltage	±15	
	Output short-circuit duration	Infinite	
R_{thja}	Thermal resistance junction to ambient DIP8 SO8	 85 125	°C/W
R_{thjc}	Thermal resistance junction to case DIP8 SO8	 41 40	
ESD	HBM: human body model(1) DIP package SO package	 500 400	V
	MM: machine model(2)	100	
	CDM: charged device model(3)	1.5	kV
T_{stg}	Storage temperature range	-65 to +150	°C

1. Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5kΩ resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.
2. Machine model: a 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω). This is done for all couples of connected pin combinations while the other pins are floating.
3. Charged device model: all pins and the package are charged together to the specified voltage and then discharged directly to the ground through only one pin. This is done for all pins.

Table 2. Operating conditions

Symbol	Parameter	UA741I	UA741C	Unit
V_{CC}	Supply voltage	5 to 40		V
V_{icm}	Common mode input voltage range	±12		
T_{oper}	Operating free air temperature range	-40 to +105	0 to +70	°C

3 Electrical characteristics

Table 3. Electrical characteristics at V_{CC} = ±15 V, T_{amb} = 25 °C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage (R_s ≤10 kΩ) T_{amb} = +25 °C T_{min} ≤T_{amb} ≤T_{max}		1	5 6	mV
I_{io}	Input offset current T_{amb} = +25 °C T_{min} ≤T_{amb} ≤T_{max}		2	30 70	nA
I_{ib}	Input bias current T_{amb} = +25 °C T_{min} ≤T_{amb} ≤T_{max}		10	100 200	nA
A_{vd}	Large signal voltage gain (V_o = ±10 V, R_L = 2 kΩ) T_{amb} = +25 °C T_{min} ≤T_{amb} ≤T_{max}	50 25	200		V/mV
SVR	Supply voltage rejection ratio (R_s ≤10 kΩ) T_{amb} = +25 °C T_{min} ≤T_{amb} ≤T_{max}	77 77	90		dB
I_{CC}	Supply current, no load T_{amb} = +25 °C T_{min} ≤T_{amb} ≤T_{max}		1.7	2.8 3.3	mA
V_{icm}	Input common mode voltage range T_{amb} = +25 °C T_{min} ≤T_{amb} ≤T_{max}	±12 ±12			V
CMR	Common mode rejection ratio (R_S ≤10 kΩ) T_{amb} = +25 °C T_{min} ≤T_{amb} ≤T_{max}	70 70	90		dB
I_{OS}	Output short circuit current	10	25	40	mA
±V_{opp}	Output voltage swing T_{amb} = +25 °C R_L = 10 kΩ R_L = 2 kΩ T_{min} ≤T_{amb} ≤T_{max} R_L = 10 kΩ R_L = 2 kΩ	12 10 12 10	14 13		V
SR	Slew rate V_i = ±10 V, R_L = 2 kΩ, C_L = 100 pF, unity gain	0.25	0.5		V/μs
t_r	Rise time V_i = ±20 mV, R_L = 2 kΩ, C_L = 100 pF, unity gain		0.3		μs
K_{ov}	Overshoot V_i = 20 mV, R_L = 2 kΩ, C_L = 100 pF, unity gain		5		%
R_i	Input resistance	0.3	2		MΩ

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(ELECTRONICS 2)

REPORT SHEET 3

OPERATIONAL AMPLIFIER

Group members	**1.**
	2.
	3.
Lecturer	**:**
Date	**:**

No.	PO	CO	Student Marks	Marks
1	PLO1	CO1		40
2	PLO2	CO2		30
3	PLO4			20
4	PO8			10
		Total Marks		/100

EXPERIMENT 3 : OPERATIONAL AMPLIFIER

A. Inverting Configuration

i) Inverting Amplifier V_S = 1V p-p

Parameter	Measured	Calculated/Nominal	Error (%)
R_1			
R_2			
R_3			
$V_{o\ (V)}$			
Gain (A_V)			

Table 1

PLO1	CLO1	……… /10m

Waveforms: vs and vo

PLO1	CLO1	……… /5m

At Clipping:

Vs (V)	
Vo_{max}(V)	
Vo_{min} (V)	

PLO1	CLO1	……… /5m

Part B : Non Inverting Configuration

V_S = 1V p-p

Parameter	Measured	Calculated/Nominal	Error (%)
V_O (V)			
Gain (A_V)			

Table 3

PLO1	CLO1	……… /7m

Waveforms: v_s and v_o

PLO1	**CLO1**	**……… /5m**

Maximum frequency (Hz)	
Minimum frequency(Hz)	

Table 4

PLO1	**CLO1**	**……… /5m**

Part C :Comparator

(i) Simple Comparator with dc input

V^+ (V)	Vo (V)
5.5	
4.5	

PLO1	CLO1	……… /5m

	V^- (V) (Pin2)	V^+1 (V) (Pin 3)	V^+2 (V) (Pin3)	(V^+1 – V^+2) V
Vo (V)				

Table 6

PLO1	**CLO1**	**……… /8m**

(ii) Comparator with triangular input

Waveforms: vs and vo

PLO1	CLO1	……… /6m

QUESTIONS

Answer the following questions

1. **Referring to Table 1 and Table 2, do the measured gains and the calculated gains agree with the expectations? Compare and discuss**

   ………
   ………
   ………
   ………

PLO1	CLO1	……… /5m

2. **How do you vary the gains of the non-inverting and inverting amplifier?**

……
……
……

PLO1	**CLO1**	**……… /3m**

3. **What is the value of the potententiometer resistance in Figure 3 to set the gain of the amplifier to 3?**

……
……
……

PLO1	**CLO1**	**……… /3m**

4. **We have seen example of clipping in an operational amplifier circuit. Explain how and why clipping should be accounted for in designing an amplifier circuit.**

PLO1	**CLO1**	**……… /4m**

5. **Why does the output signal in part A (ii) distorted?**

……
……
……

PLO1	**CLO1**	**……… /2m**

6. From your knowledge and the experiment, what is the range of frequencies that human can hear

....

....

PLO1	CLO1	.... /2m

7. From the experiment and the results in Table 6, explain how a comparator works.

....

....

....

PLO1	CLO1	.... /4m

8. For an ideal op-amp the difference between the two readings (v+1 – v+2) in Table 6 should be zero. What is the difference that you get.?

....

....

....

PLO1	CLO1	.... /3m

9. Why the observations for 7, 8 and 9 in part C (i) would be similar if the diode were connected in reverse?

....

....

....

PLO1	CLO1	.... /3m

10. Explain how the comparator circuit in part C (ii) produce the output waveform vo. Does the waveform agree with the predicted waveform?

....
....
....

PLO1	**CLO1**	**......... /5m**

11. Write the conclussion for Experiment 3

....
....
....
....
....

PLO4		**......... /6m**

PLO2 (Psychomotor/Hands On Skills) for LABS Experiments

	Criteria	Very poor (5 Marks)	Poor (10 Marks)	Moderate (15 Marks)	Good (20 Marks)	Excellent (25 Marks)
1	**Ability to perform lab works based on the manual/ guidelines provided**	Not at all	Quite Limited /Selectively	Can perform lab work moderately but require a lot of guidance	Can perform lab work systematically and only need minor guidance	Demonstrate systematic and excellent performances
2	**Ability to perform simple lab work without supervision**	Need full supervision	Major supervision	Minor supervision	Limited supervision	Work independently With no supervision
3	**Ability to carry out lab work efficiently on the following criteria, (circuit assembly, using measurement apparatus and techniques)**	Not able to construct a full circuit, poor/inaccurate measurement techniques/usage of equipment	Completed full circuit but poor/inaccurate measurement techniques/usage of equipment	Completed full circuit and it works successfully. However the measurement techniques/usage of equipment had some minor deficiency	Completed full circuit and it works successfully. However the measurement techniques/usage of equipment had produced a few errors/corrections.	Circuit was completed and works properly without any errors /corrections. Also demonstrated an excellent skills/conducts.
4	**Ability to collect the required data, performs appropriate analysis and/or troubleshooting (if necessary).**	Not able to collect data and/or perform analysis	Limited data collection but not able to perform analysis/ troubleshooting	Demonstrates major errors in data collection and /or analysis. Limited ability in troubleshooting	Minor error in data collection and analysis. Good approach/techniques in troubleshooting .	Data collection and data analysis are done systematically and performs excellent approaches to trouble shoot (if necessary)

PLO4 For Laboratory Report

	Criteria	Very Poor (5 Marks)	Poor (10 Marks)	Moderate (15 Marks)	Good (20 Marks)	Excellent (25 Marks)
1	**Data Collection**	No data reported.	Data is brief and missing significant pieces of information.	Incomplete these of components of data (Both tables and Graphes): • _____Tables • _____Graphs	Only one component of data is incomplete (either table or graph). • Tables/Graphs	Data is completed properly and attributes mentioned below are observed with great care: • Tables are easy to read and units are provided. • Graphs are labeled and shown trends.
2	**Completing/Answering Questions**	Questions are not answered at all.	Attempts were made but gave wrong answer to every question.	Questions are answered without any depth and with many errors.	Questions are properly answered but with a few errors.	Questions are answered completely and correctly.
3	**Summary/Conclusion**	No conclusion or summary is/are drawn/reported	Conclusion is too brief without any reference to important pieces of information	Any two components of the conclusion/summary (mentioned) are missing : • Summary • Data • Hypothesis • Errors	Any component of the conclusion /Summary (mentioned) is missing: • Summary • Data • Hypothesis • Errors	Conclusion /Summary of these attributes below were addressed/reported properly, clearly and systematically. • experiment, • data cited • hypothesis/assumptions made • The source of errors.
4	**Report Quality**	No attention to detail evident.	Report contains many errors.	Report is good but with few spelling or grammatical errors.	Report is well written and cohesive, with a few errors	Report is very well written without any spelling or grammatical mistakes.

PLO8 for LABS Experiments

	Criteria **-Understand the conducts, ethical values and socio-cultural impacts on professional norm and practice**	**Very poor** **(5 Marks)**	**Poor** **(10 Marks)**	**Moderate** **(15 Marks)**	**Good** **(20 Marks)**	**Excellent** **(25 Marks)**
1	**Professional Practice (Punctuality/Follow the Rules)**	Non-Conforming/In-punctuality	Not always Conforming/ Not always punctual	Sometimes Conforming/ Sometimes punctual	Conformin g /Punctual	Always Conforming /Always Punctual
2	**Ethical Conduct/Behaviour (Trustworthy / Respectfulness)**	Does not practice	Not always practicing	Sometimes only	Mostly practicing	Always practicing
3	**Social Cultural (Racial Harmony)**	Does not observe	Not always observe	Sometimes observe	Mostly observe	Always observe
4	**Personality**	Mostly unpleasant	Not always pleasant	Moderately pleasant	Mostly pleasant	Always pleasant