EE 402 LABORATORY 1
Instrument Operation and Circuit Measurements

I. Thévenin/Norton/Source Transformation

Construct the circuit in Figure 1. Using a multimeter, accurately measure the current in resistor, R_2. Treat the resistor R_2 as the load resistor and determine a equivalent Thévenin or Norton equivalent circuit. Construct this equivalent circuit and measure the load current. Compare the load current to the current that was previously measured in resistor *R2*, of Figure 1.

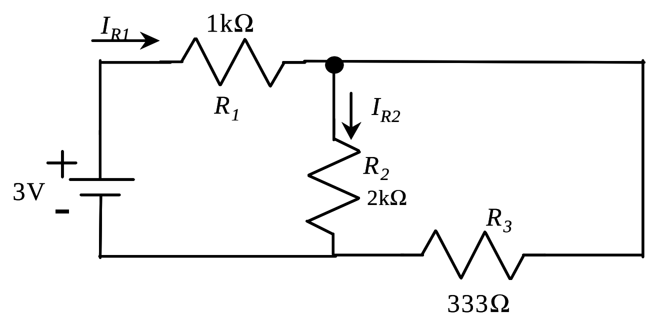


Figure 1.

II. Analog Oscilloscope and Function Generator

A. Power on the TAS 465 oscilloscope. The TAS 465 accepts signals through the front panel input connectors labeled **CH 1** and **CH 2**. The lab instructor will demonstrate various oscilloscope functions. After the demonstration, try some of the functions on your own. Use your own words in your report to describe the following.

1. Probe compensation.
   a. Explain why PROBE COMP is required.
   b. Describe the PROBE COMP signal.
   c. Describe the procedure for doing probe compensation.
2. AUTOSET.
3. Vertical Menu
4. Horizontal Menu
5. Trigger Menu
6. MAG button

B. Power on the Function Generator. The lab instructor will demonstrate how to measure the frequency, period, and amplitude of a periodic signal generated by the function generator and measured with the analog oscilloscope. After the demonstration, try to generate a square wave signal with 2 volt peak-to-peak amplitude and a frequency of 2000 Hertz.

III. Analyzing Resistor Capacitor Circuits.

A. Construct the circuit in Figure 2. As the switch is closed, measure the charging of the capacitor using an oscilloscope. Choose a resistor and capacitor combination that will allow for a long charging time. Is it possible to choose a capacitor and resistor combination that will allow the charging to be viewed on the oscilloscope? How long does it take to charge the capacitor to steady state? As you test your circuit, discharge the capacitor with the switch open and by placing a resistor across the capacitor.

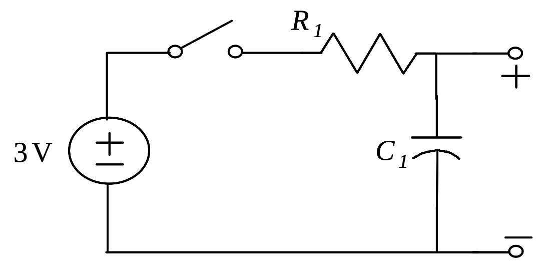


Figure 2.

B. Construct the circuit in Figure 3. Use the function generator to provide a 1 volt peak-to-peak, 2kHz square wave for v_i. Use the oscilloscope to measure the signal across the capacitor. For Figures 3 to 4, assume R_1 = 1kÙ, R_2 = 2.2kÙ, C_1=1ìF and C_2=150ìF.

1. Record your chosen sensitivities:
   Vertical sensitivity = _______________
   Horizontal sensitivity = _______________
2. Using the oscilloscope, what is the measured period of the waveform: ______________
3. In your own words, describe the process for measuring frequency, period, and amplitude.
4. Accurately sketch and completely label the output waveforms.

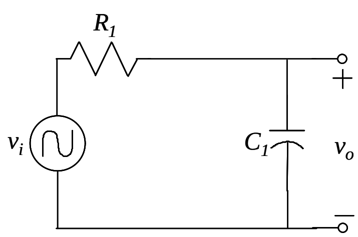


Figure 3.

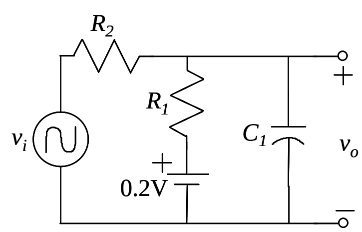


Figure 4.

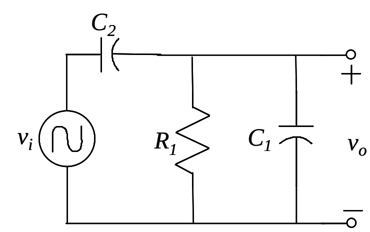


Figure 5.

C. Repeat part B for the circuit of Figure 4. Use the DC power supply to provide 0.2 V DC.

D. Repeat part B for the circuit of Figure 5 but use an input voltage sinusoidal wave with 1 volt peak-to-peak and 1kHz frequency.

E. Your report must include a complete Kirchoff and frequency analysis of the circuits as well as a theoretical versus measured analysis.

EE 402 LABORATORY 2
OPERATIONAL AMPLIFIERS

I. INVERTING AMPLIFIER - DC OPERATION

A. Construct the following op amp circuit. Use the multimeter to measure V_{in}, V_a, and V_{out} for V_{in} = 1.0V DC.

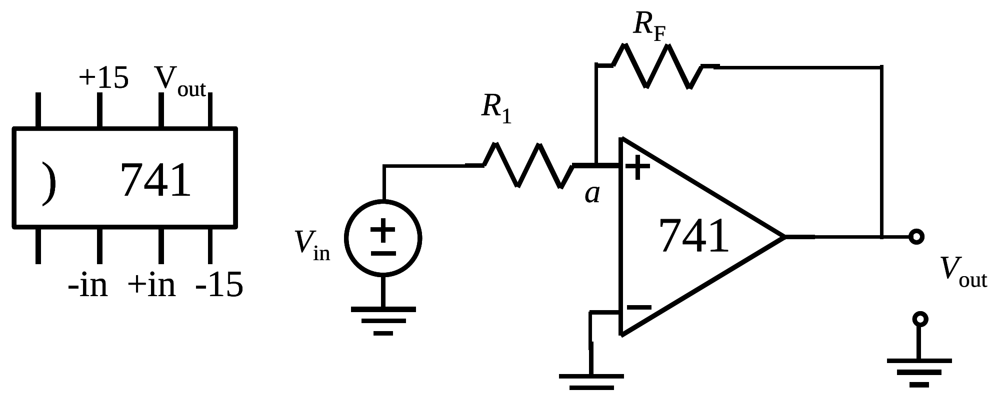


Figure 1.

B. Observe the voltages V_{in}, V_a, and V_{out} with R_f = 33kΩ and with R_1 varying from 33kΩ down to 1kΩ by increments of approximately 8kΩ. Plot $A_v = V_o/V_i$

C. What conclusions can you draw about the voltmeter reading of part B, V_a, and the Plot of A_v?

II. IDEAL DIFFERENTIATING AMPLIFIER - AC OPERATION

A. Construct the following op amp circuit. Use the oscilloscope to measure V_{in} and V_{out} for V_{in} = 3sin 2π (500)*t* V.

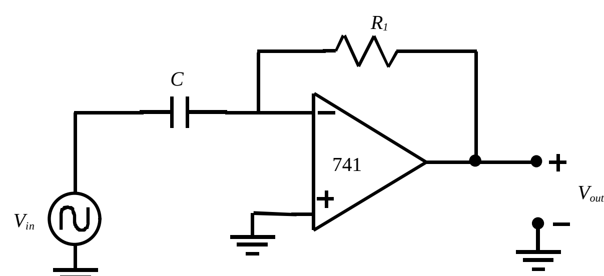


Figure 2

B. Observe the voltages V_{in} and V_{out} when R_1 = 500kΩ and C = 2ìF.

C. Observe the voltages V_{in} and V_{out} when R_1 = 1kΩ and C = .5mA. Is V_{out} in phase or out of phase with V_{in}?

III. DESIGN AN ACTIVE LOW PASS FILTER

A. Use the specification

1) Power supply ±15v
2) Roll off 20 db/decade
3) Corner frequency 1 kHz
4) Passband gain +12 db

B. Design the filter and draw Bode magnitude and phase diagrams for them.

C. Implement the filter and measure the transfer function (magnitude and phase) from 10 Hz to 20 kHz.

IV. Op Amp Oscillators

A. Read Boylestad section 18.7, pages 772-773. Construct the circuit of Figure 3 below using the values specified in Example 18.8 and V_{CC} and $-V_{EE}$ as specified in Figure 3 below. Record your measured values for resistance, V_{CC}, and $-V_{EE}$. Use the oscilloscope to measure the output voltage, V_{out}. Sketch the V_{out} waveform. What is the peak-to-peak voltage? What is the output frequency? Compare to the results of Example 18.8. Change the op amp bias voltages to V_{CC} = +9V and $-V_{EE}$ =-9V. Does changing these two voltages change the peak-to-peak voltage, the output frequency or the waveform?

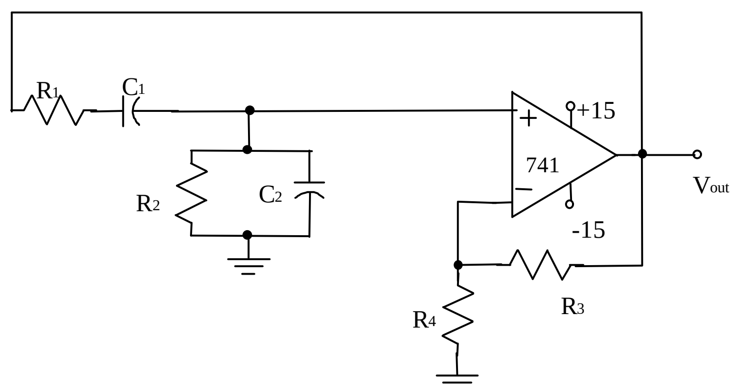


Figure 3.

B. Redesign the circuit of Figure 3 to produce a 5Khz frequency. Measure your results including measured values for resistance, V_{CC}, and $-V_{EE}$. Use the oscilloscope to measure the output voltage, V_{out}. Section 18.7 appears to only explain how to obtain a frequency from this circuit. Can you surmise from any of your observations or knowledge of Op Amps how to predict the peak-to-peak voltage for this circuit?

EE 402 LABORATORY 3

DIODE CIRCUITS: CLIPPERS, CLAMPERS, RECTIFIERS, AND VOLTAGE DOUBLER

I. DIODE Testing

A. The circuit symbol for a diode is shown in Figure 1. Choose a diode and use the diode checking function (p.35, Boylestad textbook) of the digital multimeter to determine the forward bias voltage. In your report indicate V_F using a Figure similar to Figure 1.48 on page 36 of the textbook. Based on your measurement, is this a silicon or germanium diode?

B. Use the ohmmeter technique (page 36, textbook) to determine the forward bias of the diode. Record your measurements, and state if the stripe is on the cathode or anode end. Compare to Figure 1.49 on page 36 of textbook.

C. Use the curve tracer to trace the curve of your diode. State the horizontal and vertical scales chosen for display and accurately sketch the resulting curve on graph paper.

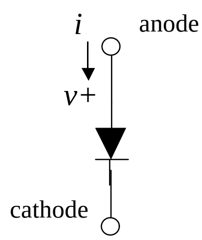
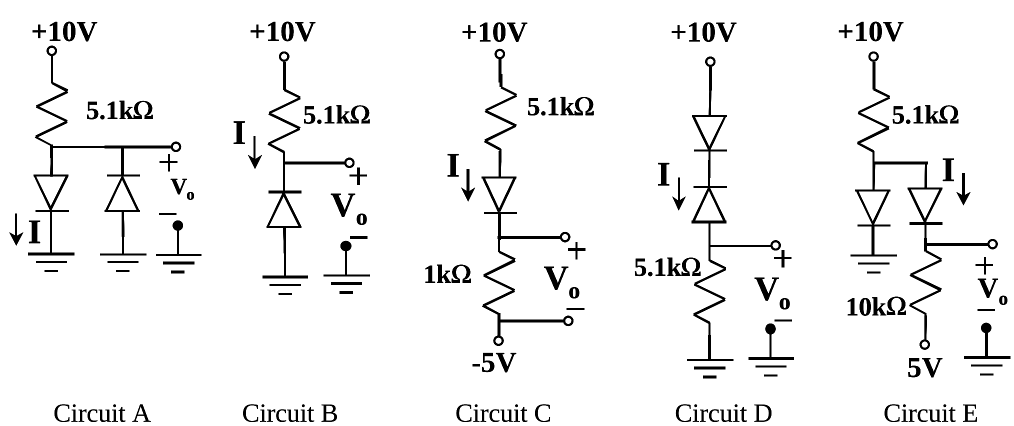


Figure 1.

II. DIODE CIRCUITS -- DC OPERATION

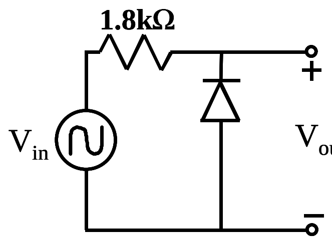
A. Construct each of these diode circuits and measure the voltage V_o. Use the measured value of V to calculate the current I in each circuit.



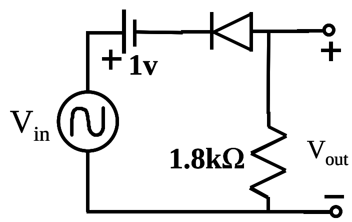
B. In your Laboratory Report, use theoretical circuit analysis to calculate V and I for each diode circuit. Compare your calculated results with the measured values.

III. CLIPPER CIRCUITS -- AC OPERATION

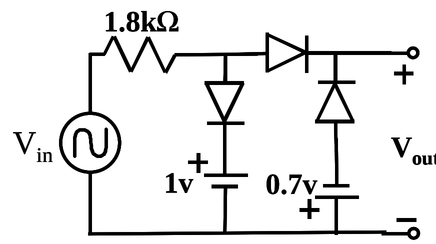
A. Construct each of these clipper circuits and measure both V_{in} and V_{out} with the dual trace scope. The voltage V_{in} is a 4 volt peak-to-peak square wave of frequency f_o = 0.5 KHz. Sketch V_{out} and V_{in} for each circuit in your laboratory report.



Circuit A



Circuit B



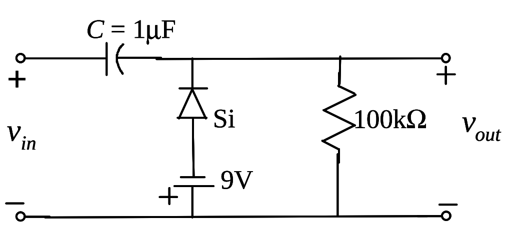
Circuit C

B. Repeat part A for $V_{in} = 2 \sin 2\pi(500)t$.

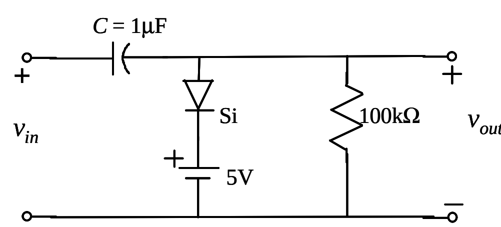
IV. CLAMPER CIRCUITS -- AC OPERATION

A. Construct each of these clamper circuits and measure both v_{in} and v_{out} with the dual trace scope. The voltage V_{in} is a 4 volt peak-to-peak square wave of frequency f_o = 0.5 KHz. Sketch v_{out} and v_{in} for each circuit in your laboratory report.

B.



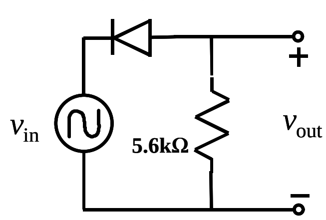
Circuit A



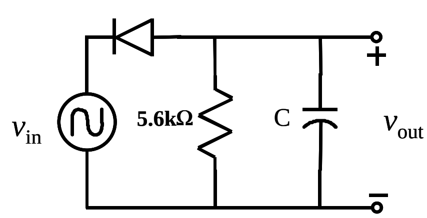
Circuit B

V. RECTIFIERS

A. **Half-Wave Rectifiers**. Construct each of these half-wave rectifier circuits and measure both v_{in} and v_{out} using the dual trace scope. Sketch the voltage waveforms v_{in} and v_{out} in your Lab Report. The voltage v_{in} is $v_{in} = 3\sin 2\pi(500)t$. Try C=1pF, 1ìF, 10ìF.



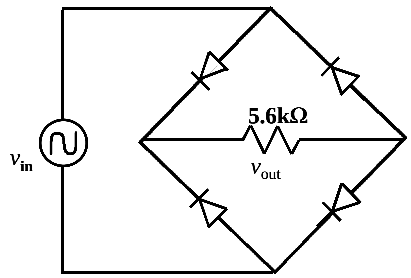
Circuit A



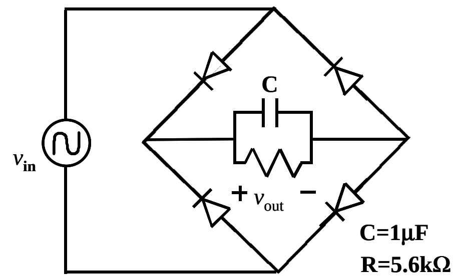
Circuit B

B. Repeat part A for v_{in}, a 3 volt peak-to-peak triangular wave of frequency f_o = 500Hz.

C. **Full-Wave Rectifiers**. Construct each of these full-wave rectifiers and measure both V_{in} and V_{out} using the dual trace scope. Sketch the voltage waveforms V_{in} and V_{out} in your Lab Report. To measure the voltage V_{out} in these circuits, you must use the differential mode on the scope. The voltage V_{in} is $V_{in} = 3 \sin 2\pi(500)t$.



Circuit A

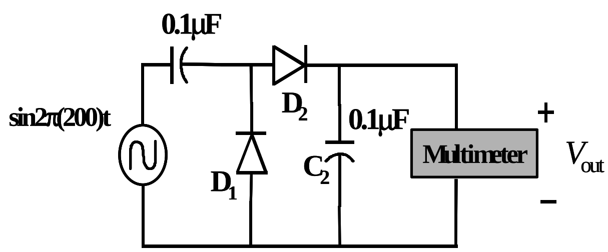


Circuit B

D. Repeat part C, CKT B for the additional capacitor values of C = 0.1ìF, and C = 10ìF.

VI. VOLTAGE DOUBLER

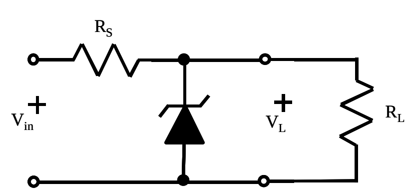
The voltage doubler can be thought of as two sections in cascade: a clamp formed by C_1 and D_1 and a peak rectifier formed by D_2 and C_2. When $V_{in}(f) = V_{in} \sin \omega_m t$, the output voltage, V_{out}, should be $2V_{in}$. Construct the doubler circuit as shown in the figure below using the multimeter set on DC volts to measure V_{out}.



Once you have the circuit in operation, vary V_{in} and ω_m to observe that the circuit acts as a voltage doubler over a range of frequencies and amplitudes.

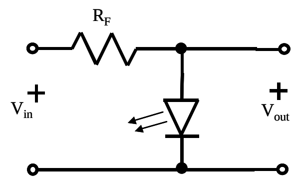
VII. VOLTAGE REGULATOR

The zener diode is used to regulate voltage. Determine R_L and R_S and the range of values that will allow V_L to regulate the voltage within 5% of the desired V_{in} of ________.



VIII. Light-Emitting Diode

Construct the light-emitting diode circuit and vary V_{in} from 0 to 3V. Measure V_{out}, and V_F. Calculate I_F. Measure the relative luminous intensity using a light meter. Create graphs showing how relative intensity varies with the forward current and forward voltage. Also show how the I_F and V_F relate graphically. Try R_F=1kÙ.



IX. LABORATORY 3 SUPPLEMENT

EE 402 LABORATORY 4

BIPOLAR JUNCTION TRANSISTOR (BJT)

Characteristics, DC Bias Circuits, and Operating Point

I. OBJECTIVE

The objective of this exercise is to investigate the characteristics of a bipolar junction transistor (BJT), analyze and design a DC Bias Circuit, its Operating Point, and Region of Operation for amplification.

II. DISCUSSION

Transistors come in different packaging. Figure 1 shows a bipolar junction transistor (BJT) in the TO-92 package. But however they are packaged, the BJT will have a lead for the base, the emitter, and the collector as shown in Figure 2. The emitter has an arrow pointing in the direction of "conventional" current flow. The BJT consists of only two combinations of n-type and p-type material: either p-type material sandwiched between two n-type materials called npn, or n-type material sandwiched between two p-type materials. In the first part of this laboratory, you will determine the transistor material (Si or Ge), transistor type (npn or pnp), and which terminal on the transistor is base, which is collector, and which is emitter. Read section 3.10 and 3.11 of Boylestad textbook, pages 153 to 156.

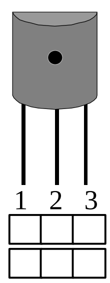


Figure 1.

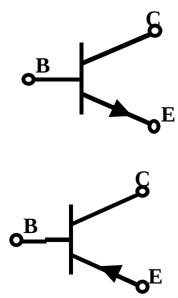


Figure 2.

III. PROCEDURE*

A. **Material, Type and Terminals of a BJT**

For the 2N3904 transistor, label the transistor terminals 1, 2, and 3 as shown in Figure 1. Set the multimeter selector switch to the diode scale. Place the meter leads on the transistor terminals as shown in table 1 and record your diode scale readings . Set the selector switch to approximately the 2kΩ resistance range. Place the meter leads on the transistor terminals as shown in table 1 and record your resistance readings.

Multimeter leads on BJT Terminals		Diode Scale	Resistance
Positive	Negative		
1	2		
2	1		
1	3		
3	1		
2	3		
3	2		

Table 1.

Justify your answers to the questions below based on the values recorded in Table 1.

1. Which terminal is the base?
2. Is it pnp or npn?
3. Which terminal is the collector?
4. Which terminal is the emitter?
5. What is the material type?
6. Do you think this transistor will work?

B. **BJT Characteristics Curves**

1. Use the curve tracer and the procedure outlined in section 3.10 of the Boylestad textbook to obtain the I_C vs. V_{CE} curve of your 2N3904 transistor. Make an accurate sketch of the curve tracer results on graph paper. From the curve trace approximate the value of Beta (â) at different values of I_C and compare to the values of h_{FE} shown on the specification sheet. Explain reasons for variations.

2. Measure the characteristics of the BJT transistor using the circuit of Figure 3.

a. Set the voltage V_{RB} to 2.7V by varying the 2MΩ potentiometer. This will set I_B to 10µA since $I_B = V_{RB}/R_B$. Next, set V_{CE} to 1V by varying the 10kΩ potentiometer. The values for V_{RB}, I_B, and V_{CE} now match the values of the first row in Table 2. Measure voltages V_{RC} and V_{BE} and record in Table 2. Now vary V_{RB} and V_{CE} to the values shown in Table 2 and fill in the remaining measured V_{RC} and V_{BE} values.

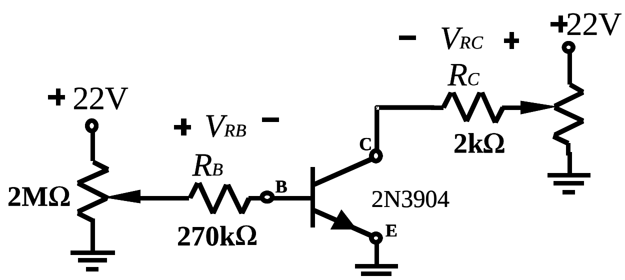


Figure 3.

b. Calculate the values of I_C, I_E, α, and β using the formulas: $I_C = V_{RC}/R_C$, $I_E=I_C+I_B$, $\alpha=I_C/I_E$, and $\beta = I_C/I_B$ (Use the measured value of R_C in your calculation).

c. Plot I_C versus V_{CE} for the various values of I_B. Label your graph completely. Mark the largest and smallest values of β on the graph using notation β_{max} and β_{min}.

d. In your report, answer these questions. Is there a significant variation in α and β in the different regions of the curve on the graph? At what I_C vs.V_{CE} value is the largest value of β found? At what I_C vs.V_{CE} value is the smallest value of β found? In general, did β increase or decrease with increase in I_C? In general, did β increase or decrease with increase in V_{CE}? Was the effect on β greater or less than the effect on I_C? Using Table 2, what is the average value of β? Where on the graph does the average value of β typically occur? Is this average value of β reasonable to use for most applications? Calculate the average value of V_{BE} from the table and comment on whether it is reasonable to use 0.7 V in the analysis of BJT transistor networks when the actual value is unknown?

V_{RB} (V)	I_B (mA)	V_{CE} (V)	V_{RC} (V)	I_C (mA)	V_{BE} (V)	I_E (mA)	α	β
2.7	10	1						
2.7	10	3						
2.7	10	5						
2.7	10	7						
2.7	10	9						
2.7	10	11						
2.7	10	13						
2.7	10	15						
5.4	20	1						
5.4	20	3						
5.4	20	5						
5.4	20	7						
5.4	20	9						
5.4	20	11						
5.4	20	13						
8.1	30	1						
8.1	30	3						
8.1	30	5						
8.1	30	7						
8.1	30	9						
8.1	30	11						
8.1	40	1						
8.1	40	3						
8.1	40	5						
8.1	40	7						
8.1	40	9						
10.8	50	1						
10.8	50	3						
10.8	50	5						
10.8	50	7						

Table 2.

e. In your report, compare your results to the textbook curve trace and to the curve tracer output for the 2N3904 transistor.

4. Determine β_{ac} as outlined in section 3.10 for a quiesent point of I_C = 7ma and V_{CE} = 5V. Compare your results with the textbook results and theoretical results.

IV. BJT Amplification Circuit Design

A. You are required to design a circuit that will amplify millivolts given by V_{signal} to volts at V_{CE}. Based on the I_C vs. V_{CE} characteristic curve and the region of operation as defined by the maximum power dissipated, P_D (see spec sheet), use the circuit in Figure 4 for your design with an operating point (quiescent point) centered in the operating region. For your choice of resistors, define the range of a sinusoidal signal V_{signal} and the amplification range output for that sinusoidal signal at V_{CE}.

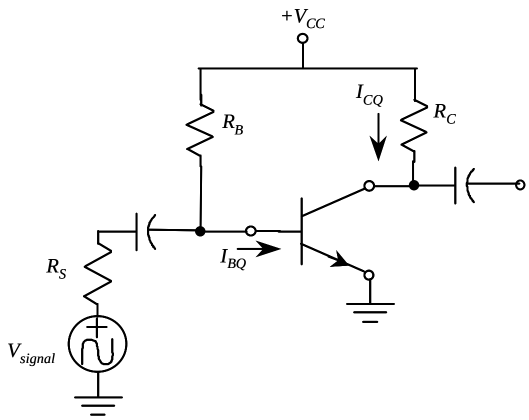
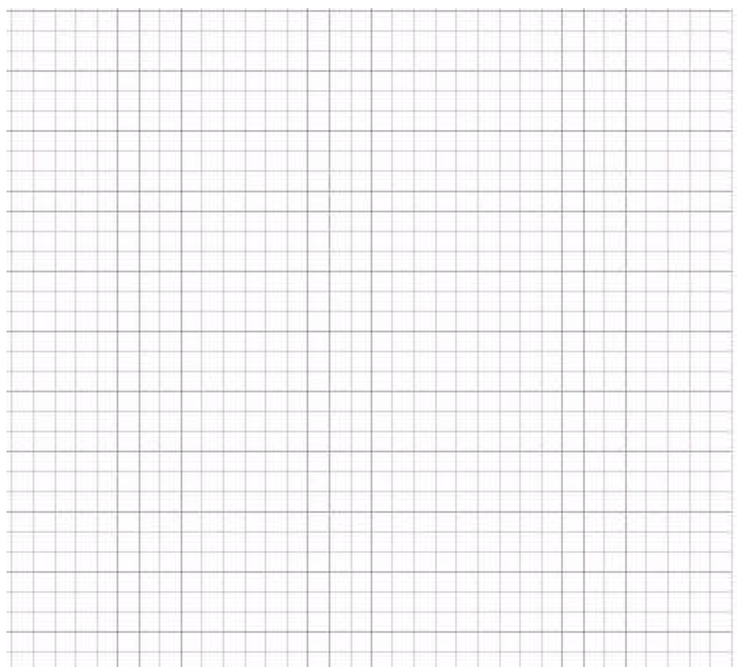


Figure 4.

B. Draw two additional I_C vs. V_{CE} characteristic curves: one theoretical and one actual I_C vs. V_{CE} characteristic curve for the BJT transistor used above. Sketch the region of operation, the load line, and the sinusoidal range of values for I_B, I_C, and V_{CE} on both curves placing the theoretical values on the theory sketch and the observed values on the actual curve. LAbel completely, compare and comment on the results.

V. SUPPLEMENTAL

***Warning: Disconnect power supply when changing transistors in the circuit.**



EE 402 LABORATORY 5
N-CHANNEL DE FIELD EFFECT TRANSISTOR – 2N5459

I. OBJECTIVE

The objective of this lab experiment is to measure the characteristics of the field effect transistor (FET) and observe the FET performance in a basic amplifier circuit.

II. DISCUSSION

Manufactured JFETs vary quite a bit even if they are the same type. Manufacturers often do not always publish the characteristic and transfer curve but provide values for pinchoff voltage, V_p, and the saturation current, I_{DSS}. This suggests other approaches for determining the quiescent condition for a JFET by varying V_{GS}.

III. PROCEDURE

Construct the following self-bias circuit:

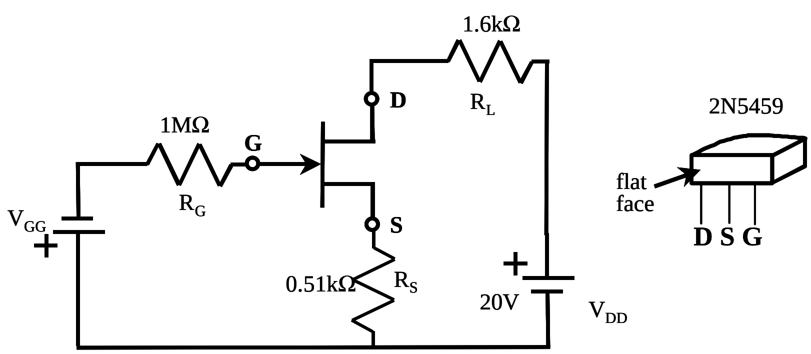


Figure 1.

A. Measure V_{DS} for V_{GS} varying from 0 to -5V in steps of 0.5 V. Calculate I_D for each of the measurements (Instead of 2.11kÙ, use the actual measured resistance).

$$I_D = \frac{V_{DD} - V_{DS}}{R_L + R_S} = \frac{20 - V_{DS}}{2.11\text{k}\Omega}.$$

Plot I_D versus V_{GS}. Note the values of I_{DSS} and $V_{GS(off)}$ on your graph. Estimate the value of the forward transfer admittance at $V_{GS} = 0$ by making the following calculation:

$$g_{mo} = \left.\frac{\Delta I_D}{\Delta V_{GS}}\right|_{V_{GS}=0} = \frac{I_D\big|_{V_{GS}=0} - I_D\big|_{V_{GS}=-0.5}}{0.5}.$$

Compare your values of I_{DSS}, $V_{GS(off)}$, and g_{mo} to the manufacturer's value below.

	MIN	*TYP*	*MAX*
I_{DSS}(mA)	4	9	16
$V_{GS(off)}$(V)	-2	-5	-8
g_{m0}(ms)	2	4.5	6

B. For V_{GS} = 0 (i.e., gate shorted to source), change V_{DD} from 0 to 20V in steps of 1V. Measure V_{DS} and calculate I_D for each measurement. Plot I_D versus V_{DS} for V_{GS} = 0. Estimate the value of r_d, the dynamic drain resistance, by making the following calculation:

$$r_d = \left.\frac{\Delta v_{DS}}{\Delta I_D}\right| = \frac{V_{DS}\big|_{V_{DD}=17} - V_{DS}\big|_{V_{DD}=13}}{I_D\big|_{V_{DD}=17} - I_D\big|_{V_{DD}=13}}.$$

The data measured to this point permits the following small signal model of the FET to be constructed assuming the quiescent point is determined by V_{DD}=20V, V_{GS}=0V and R_L=1.6KΩ.

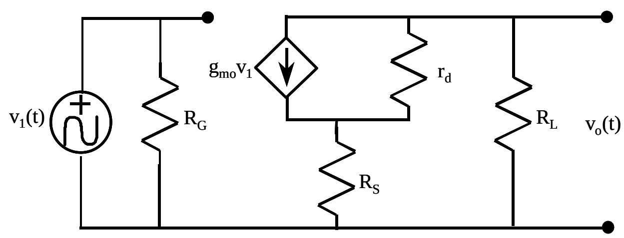


Figure 2.

The theoretical AC voltage gain obtained from this small signal model is derived in Boylestad in chapter 9, section 9.4 on pp. 475-478

$$\frac{v_0}{v_1} = -g_{mo}\left[\frac{R_L}{1 + g_{mo}R_s + \dfrac{R_s + R_L}{r_d}}\right].$$

Using the values of g_{mo} and r_d previously obtained, calculate the expected voltage gain.

C. Construct the circuit of Figure 3, basic AC amp, with $v_1(t) = 1.0 \sin 2\pi(1000)t$ V, measure $v_0(t)$ and determine $v_0(t)/v_1(t)$. Compare to the value obtained from the small signal model.

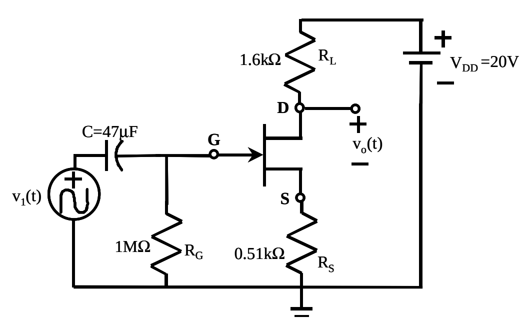


Figure 3.

D. Vary the frequency of $v_1(t)$ and measure $v_1(t)$ and $v_0(t)$ to obtain a frequency response curve for the magnitude of the voltage gain $A = |v_0(t)/v_1(t)|$. Plot on semi-log paper the value of $20 \log_{10} A$ versus frequency (frequency on log scale).

IV. REPORT

1. Measurements and graphs required in procedure.
2. Discuss measured results versus theoretical values where appropriate.
3. In your analysis construct a plot of I_D versus V_{GS} by varying V_{GS} from 0 to -5V.

V. LABORATORY 5 SUPPLEMENT

EE 402 LABORATORY 6
MICROPROCESSOR

I. OBJECTIVE

The purpose of the experiment is to learn how to enter and run simple programs on the MEK6802D5 board. We will learn how the display portion of the board works. We will develop an algorithm and assembly code to multiply two four bit numbers using the 6802 microprocessor. We will also develop a program to perform double precision addition.

II. DISCUSSION

The Motorola MEK6802D5 is an inexpensive microcomputer based on the widely used Motorola 6802 microprocessor. It is composed of the following components:

MC6802	serves as the central processor unit
MC68A316E	rom-read only memory which contains the monitor program DEBUG
MC6821	pia-peripheral interface adapter for inputs or outputs
RAM	random access memory to store data and programs
LED Display	
Keyboard	

The student can refer to the MEK6902D5 microcomputer evaluation board user's manual for details about the hardware and information on available monitor routines. The MEK6802D5 accesses 684K of memory space by use of 16 address lines. The system memory map is shown in Figure 1 (next page). User memory or optional user memory is available for your use.

III. PRELABORATORY ASSIGNMENT (PLAs)

PLA1	5C	2F	AE	80	AA	+8A	At left are several 8-bit two's help complement
	-AB	-9C	+44	-D3			numbers (HEM) to you familiarize yourself
	39	2C	FF	44	C6	-	with HEX addition & subtraction. Show the8-
	B1	-FD	-EF	+CD	-B7		bit result & ignore any carry bits beyond 8 bits

PLA2 Explain how to reset the 6802D5 board & also how to exit the program w/o doing a system reset.

PLA3 Describe the technique of examining memory locations .

IV. EXPERIMENT

A. Reset the system, then examine and record the value of each register in the 6802 CPU.

B. Below are two short programs. The first adds the current contents of the B accumulator to the current contents of A accumulator. The second program subtracts the current contents of B accumulator from the current contents of the A accumulator. Deposit these programs in memory at addresses E000 and E100, respectively. Use these programs to check the results of your prelab exercise. Note each result and discuss range of accurate addition and subtraction. Also indicate what indication you have from the microprocessor that your addition or subtraction is inside or outside the range of accuracy.

Program 2 1B 3F
Program 3 10 3F

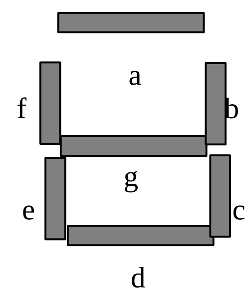
M E M O R Y   M A P

0000	USER MEMORY
007F	
0080	NO MEMORY INSTALLED
E000	OPTIONAL USER MEMORY
E3FF	
E400	SYSTEM MEMORY
E47F	
E480/83	USER PIA
E484/87	SYSTEM PIA
E489	RESERVED
E6FF	
E700/01	SYSTEM ACIA
E702/FF	RESERVED
E800	USER MEMORY
EFFF	
F000	SYSTEM MEMORY
FFF	

Figure 1.

C. Development of a program to display simple messages.

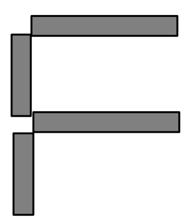
This experiment should give us a better understanding of how numbers and letters are displayed on the micro-processor. The seven segment bit relationship is shown in the figure with a letter related to each f segment. To turn on any segment, a high(1) bit for that segment is required. A low(0) bit for a segment means it is off. The full instruction for the display is arranged as follows:



0	g	f	e	d	c	b	a

For example, to display the character ‘F’ in the instruction would be

a-1
b-0
c-0
d-0
e-1
f-1
g-1



The HEX representation of "F" is 71_{16}. Note that all numbers 0 to 9 can be displayed, but not all characters can be displayed. For example "T" and "I" cannot be displayed. To display "B" and "D" display "b" and "d".

Display Program

Enter the following display program on the microprocessor.

Location	Code	Mnemonic	Instruction and Effect
E000	CE	LDX 7171	Load register X with "FF"
E001	71		
E002	71		
E003	FF	STX DISBUF	Store "FF" in system memory at E41D
E004	E4		
E005	1D		
E006	CE	LDX 7171	Load register X with "FF"
E007	71		
E008	71		
E009	FF	STX DISBUF+2	Store "FF" in system memory at E41F
E00A	E4		
E00B	1F		
E00C	CE	LDX 4040	Load register X with "--"

Location	Code	Mnemonic	Instruction and Effect
E00D	40		
E00E	40		
E00F	FF	STX DISBUF+4	Store "-" in system memory at E421
E010	E4		
E011	E	LDX DIDDLE	Load register X with DIDDLE ROUTINE
E013	FO		
E014	A2		
E015	FF	STX MNPTR	Establish an active sub of PUT
E016	E4		
E017	19		
E018	7E	JMP PUT	Call display routine
E019	FO		
E01A	BB		

E01B 3F STOP

After entering this program into memory, enter E000 and press "GO" to begin execution. The display should read FFFF- -.

Display Message Using Display Program

Determine the display instructions to display EE-LAB . Change the program of part 4.5.2 and run the program to display EE-LAB . Repeat for the display of HELLO- .

Adding a Delay to the Display Program

This part will give us a better understanding of the PUT/MNPTR routine operation. DIDDLE has been used so far as the subroutine which is executed once each millisecond from PUT. Now substitute a long delay using the DLYX routine as the subroutine which is specified by MNPTR.

E01B	CE	LDX FFF	Give about a 1/2 sec delay
E01C	FF		
E01D	FF		
E01E	BD	JSR DLYX	Delay
E01F	F1		
E020	79		
E021	39	TS	Return to PUT
E022	F5		
E023	3F		STOP

To install SLOW as the active subprogram of PUT, just change the line E012 of the program of Section 4.5.2:

was

E012	CE	LDX DIDDLE	
E013	FO		
E014	A2		

change to

E012	CE	LDX SLOW	Load SLOW routine
E013	EO		
E014	1B		

Run the display program with these changes. When the program is running between successive digits (which are on for about 1 millisecond) there is approximately a half second delay. Adjust the amount of the delay by changing the FFFF at lines E01C and E01D and observe the effect. A.

V. Multiplication

A. The 6802 does not have a multiplication instruction. If we wish to multiply two numbers we must write a program to do so. We are all familiar with multiplication of decimal numbers. For example,

15	multiplicand
<u>14</u>	multiplier
60	
<u>15</u>	partial products
210	product

The upper partial product is the sum of (15 + 15 + 15 + 15) = 60. The lower partial product is the sum of 10 (ten) 15's. If two four bit numbers are multiplied, the result is an eight bit number. The 6802 accumulators A and B will handle eight bit numbers so the product of two four bit numbers can be stored without having to resort to the use of other registers. If two eight bit numbers are multiplied, the result is a sixteen bit number of which only eight bits will be in accumulator A or B. There are several algorithms available which allow the multiplication of two numbers as large as sixteen bits. The multiplication of two four bit numbers is less cumbersome and may be implemented in several ways using the Executable Instructions for the 6802. The student can easily develop an algorithm and assembly code.

B. Develop an algorithm and code to multiply two four bit numbers.

C. Program the MEK 6802D5 microcomputer with your code and verify that the program works for the product of any positive four bit number with any other positive four bit number.

VI. Double Precision Addition

A. Develop an algorithm and code to do double precision addition on the microprocessor. Program P6 does single precision addition of two 8 bit numbers. Thus in double precision addition, there is the addition of two 16 bit numbers. A suggested program for double precision addition is listed on the next page. Only the memory location and code are given. As part of the lab write up, you should add the mnemonics, instruction and effect for each line of code. Each 16 bit number is divided into two 8 bit numbers called MS (most significant) and LS (least significant) bytes. These sets of 8 bit (one byte) numbers are placed in memory locations:

E060 LS byte of first number
E061 MS byte of first number
E070 LS byte of second number
E071 MS byte of second number.

The results of the addition are placed in memory locations:

E050
E051
E052

B. Demonstrate the program works for the sum of any combination of 16 bit numbers.

VII. LABORATORY 6 SUPPLEMENT

DOUBLE PRECISION ADDITION PROGRAM

Location	Code
E000	F6
E001	E0
E002	60
E003	FB
E004	E0
E005	70
E006	F7
E007	E0
E008	50
E009	F6
E00A	E0
E00B	61
E00C	F9
E00D	E0
E00C	F9
E00D	E0
E00E	71
E00F	F7
E010	E0
E011	51
E012	C6
E013	00
E014	59
E015	F7
E016	E0
E017	52
E018	3F