INSTRUCTION OF ANALOG CIRCUIT EXPERIMENTATIONS

CONTENT

Experiment 1 Single Stage Amplifier Circuit

Objective

1. To be familiar with the electronic components and the digital-analog training system.
2. To master the adjusting methods of amplifier quiescent point and their effect on the performance of the amplifier.
3. To study the measuring methods of amplifier point Q, Av, r_i, r_o, and understand the common emitter circuit features.
4. To study the dynamic performance of the amplifier.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-011(A1)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

1. Circuit set up

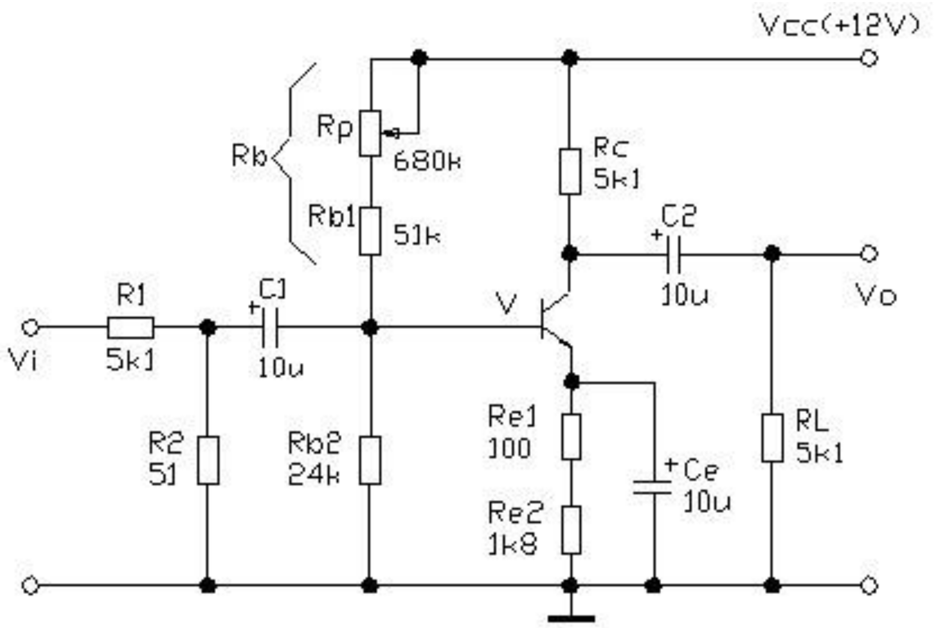

Figure 1.1 single stage amplifier circuit (A1)

(1) Use the digital multimeter to judge the transistor V on the circuit board is good or bad and determine the polarity. Do the same to the electrolytic capacitor C.
(2) Set up the circuit as figure1.1 (notice: test the power voltage 12V first and connect it last), adjust the value of $R_{p.}$ to max.
(3) Check the circuit and make sure it is correct then connect the power. Change R_p and record the β values of the transistor V at 0.5 A, 1 A, 1.5 A(notice the measurement and calculation methods of I_b)。

2. Static adjust

Adjust R_p and make V_E=2.2V， calculate and tabulate the data in table 1.1

Measure			Calculate	
V_{BE}(V)	V_{CE}(V)	R_b(KΩ)	I_B(μA)	I_C(mA)

Table 1.1

3. Dynamic analyze

(1) Adjust the function generator of M21-7000, output frequency f=1KHz and amplitude v=3mV, connect it to V_i the input terminal of the amplifier, observe the waveform and compare the phase of V_i and $V_{0,}$.

(2) Keep the frequency f=1KHz and increase the amplitude gradually to get the maximum undistorted output voltage. Tabulate it in table 1.2. (notice: A_v= voltage gain, R_L=∞）

Measure		Calculate	Estimate
V_i(mV)	V_0(V)	A_v	A_v

Table 1.2

(3) Keep the input voltage V_i＝5mV，load R_L connected，change R_C and measure repeatedly, tabulate the results in table 1.3

Given parameters		Measure		Calculate	Estimate
R_C	R_L	V_i(mV)	V_0(V)	A_v	A_v
2K	5K1				
2K	2K2				
5K1	5K1				
5K1	2K2				

Table 1.3

(4) Keep the input voltage V_i＝5mV，change R_P，observe the waveform of V_0，measure and tabulate the results in table 1.4

R_P	V_b	V_c	V_e	V_0 waveform
max.				
moderation				
min.				

Table1.4

Notice: If the waveform distortion is not obvious, change V_i and repeat (4).

4．Amplifier input and output resistance measure

(1) Input resistance measure

Series connect a resister 5K1 to the input port as Figure 1.2, measure V_s and V_i, thus calculate r_i.

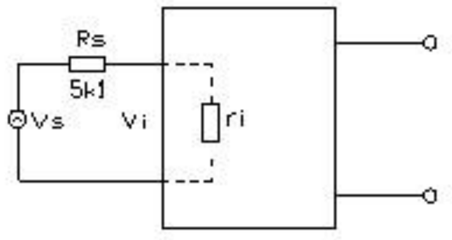

Figure 1.2

(2) Output resistance measure

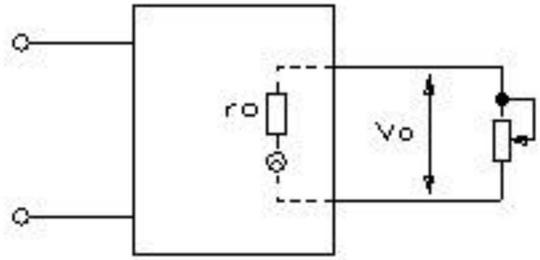

Figure1.3

Connect a potentiometer as load, R_L value according to undistorted amplifier output (with oscilloscope), measure the output voltage with load and without load, thus calculate r_o.

Tabulate the results in table 1.5

Input resistance (R_s = 5K1)				Output resistance			
Measure		Calculate	Estimate	Measure		Calculate	Estimate
V_s(mV)	V_i(mV)	r_i	r_i	V_o $R_L=\infty$	V_o $R_L=$	V_o(KΩ)	V_o(KΩ)

Table 1.5

Experimental report

1. Indicate the experiment content you have completed and the considered questions, and briefly describes the relevant basic conclusions.
2. Choose one of the most impressive experiment content in the experiment, write a detailed report. Request you to make some one only knows electronic circuit principle but haven't seen the INSTRUCTION can read your test report, and understand your experiment basic conclusions.

Experiment 2 Two Stage Amplifier Circuit

Objective

1. To master how to set quiescent point.
2. To study the measuring methods of amplifier frequency response.
3. To know amplifier distortion and the reducing methods.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-011(A3)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

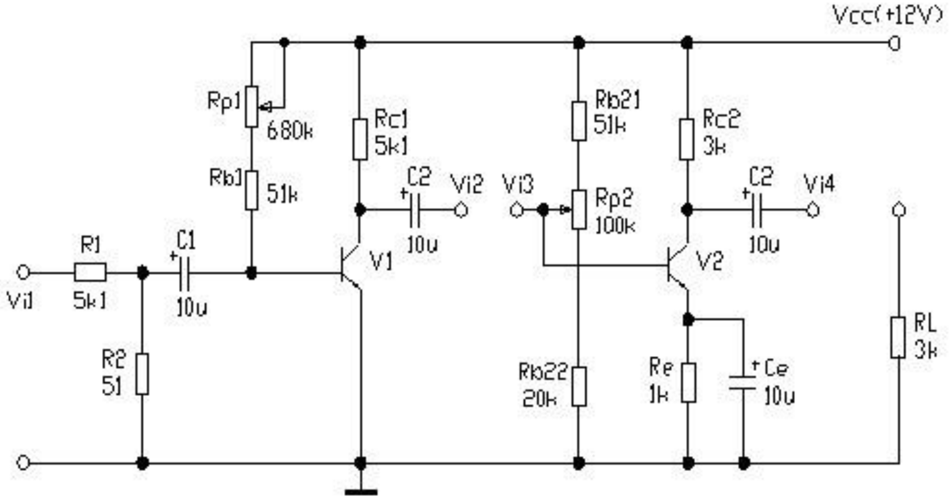

Figure 2.1 two stage AC amplifying circuit (A3)

1. Set quiescent point

(1) Set the circuit as Figure 2.1, pay attention to the wiring as short as possible.

(2) Quiescent point set: the best second stage point of getting maximum undistorted output amplitude, and the first stage point as low as possible to increase the signal to noise ratio.

(3) Connect AC signal of 1kHz and 1mV to Vil, the input terminal of the amplifier (usual use amplitude attenuation way, such as 100mV amplitude through 100:1 attenuation resistors on the circuit board to get 1mV). Adjust the quiescent point,

thus output signal is not distorted.

Notice: parasitic oscillation occur, use the following procedure to clean up:

a) Re-routing, circuit as short as possible.

b) Join up a picofarads or hundred picofarads capacitance between the base and the emitter terminals.

c) The signal source and the amplifier are connected with shielded cable.

2. In no load condition, measure and calculate according to the requirements of table 2.1. Pay attention to measuring the quiescent point when the input signal is disconnected.

	Quiescent point						Input/output voltage (mV)			Voltage gain		
	First stage			Second stage						First stage	Second stage	Total
	V_{c1}	V_{b1}	V_{e1}	V_{c2}	V_{b2}	V_{c2}	V_i	V_{01}	V_{02}	A_{v1}	A_{v2}	A_v
No load												
Load												

Table 2.1

3. Join up a load resistor R_L = 3 KΩ, measure and calculate according to Table 2.1, compare the results with 2.

4. Measure the two stage amplifier frequency response.

(1) Disconnect the load, the input signal frequency is 1 KHz, and the amplitude is based on getting maximum undistorted output amplitude.

(2) Keep the amplitude and change the frequency, measure and tabulate the results in table 2.2.

(3) Connect the load and repeat (2).

f(Hz)		50	100	250	500	1000	2500	5000	10000	20000
V_0	$R_L=\infty$									
	R_L=3K									

Table 2.2

Experimental report

1. Finish the experimental data, analyze the experimental results.
2. Draw a chart of the amplifier frequency response, mark f_H and f_L.
3. Put forward a way to increase frequency response.

Experiment 3 Negative Feedback Amplifier Circuit

Objective

1. To study how does negative feedback affect amplifier performance。
2. To master the test methods of the feedback amplifier performance.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-011(A3, A4)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

1.Measure negative feedback amplifier open-loop and closed-loop gain

1) Open-loop circuit

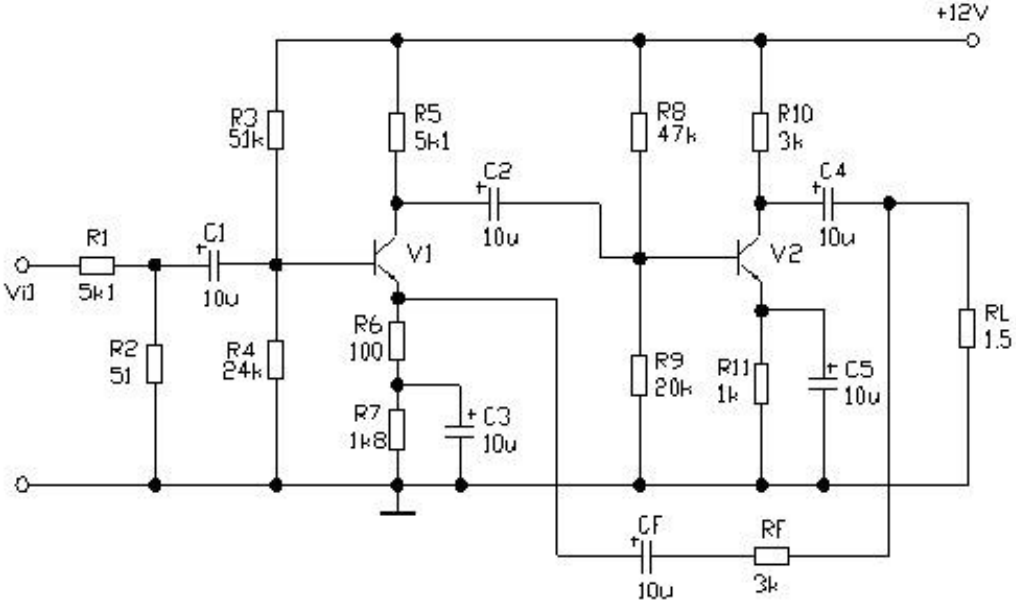

Figure 3.1 negative feedback amplifier circuit (A3, A4)

① Set the circuit as Figure 3.1, R_F open.

② Connect AC signal of 1kHz and 1mV to Vil, the input terminal of the amplifier, eliminate distortion and oscillation (same way as **experiment 2**).

③ Measure and tabulate according to the requirements of table 3.1.

④ Calculate open-loop gain A_v .

2) Closed-loop circuit

① R_F close and be sure no distortion and no oscillation.

② Measure and tabulate according to the requirements of table 3.1, calculate closed-loop gain A_{vf}.

③ Verify $A_{vf} \approx \frac{1}{F}$.

	$R_L(K\Omega)$	V_i(mV)	V_0(mV)	A_V (A_{Vf})
Open-loop	∞	1		
	1K5	1		
Closed-loop	∞	1		
	1K5	1		

Table 3.1

2. Negative feedback effect on reduce distortion

(l) Open the loop, increase the amplitude of V_i until output distortion. Record the amplitude.

(2) Close the loop, observe the output waveform, increase the amplitude of V_i until the output amplitude no change.

(3) Connect feedback to the base of V1, verify the result.

(4) Draw all waveforms of each step.

3. Measure amplifier frequency response

(l) Open the loop, a proper amplitude input (1kHz) to get a complete sine output display on oscilloscope.

(2) Keep the input amplitude and increase the frequency until output amplitude 30% off. This frequency is f_H of the amplifier.

(3) Same way, but reduce frequency to get f_L.

(4) Close the loop, repeat (1), (2), (3) and tabulate the results in table 3.2

	f_H(Hz)	f_L(Hz)
Open-loop		
Closed-loop		

Table 3.2

Experimental report

1. Compare the experimental value with the theoretical value, analyze the error.
2. Summarize the effect of negative feedback on amplifier performance.

Experiment 4 Emitter Follower

Objective

1. To master the characteristics of the emitter follower and the measurement method.
2. To furtherly study amplifier parameters measurement method.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-011(A2)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

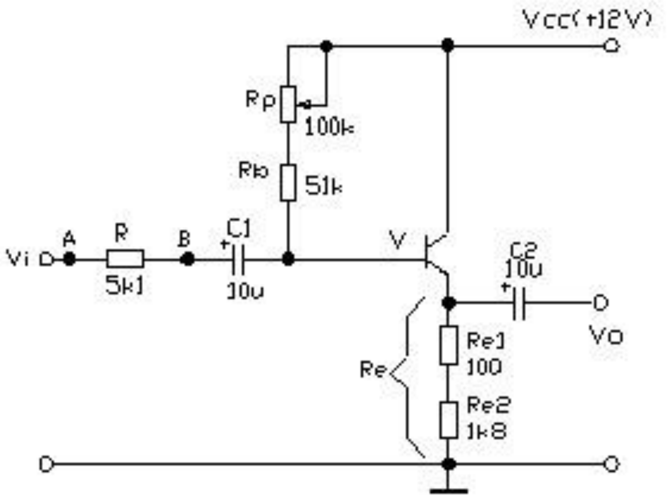

Figure 4.1 emitter follower circuit (A2)

1. Set the circuit as Figure 4.1.
2. Adjust quiescent point.

Connect a sine signal of 1kHz to B point, observe the output by oscilloscope, adjust R_P and the output amplitude repeatedly to get a maximum undistorted waveform. Then disconnect the input signal, test each pole levels of the transistor, the amplifier quiescent point. Tabulate the results in table 4.1.

$V_e(V)$	$V_b(V)$	$V_e(V)$	$I_e=\frac{V_e}{R_e}$

Table 4.1

3. Measure voltage gain A.

Connect a load R_L=1KΩ and a sine signal of 1kHz to B point, observe the output by oscilloscope, adjust the input amplitude to get a maximum undistorted output, test V_i and V_L. Tabulate the results in table 4.2.

$V_i(V)$	$V_L(V)$	$A_v=\frac{V_L}{V_i}$

Table 4.2

4. Measure output resistance R_O.

Connect a sine signal of 1kHz and 100mV to B point and a load R_L=2K2Ω, observe the output by oscilloscope. Test the both output voltage V_0（$R_L=\infty$) and V_L(RL =2K2Ω0.

Thus $$R_O=\left(\frac{V_0}{V_1}-1\right)R_L$$

Tabulate the results in table 4.3.

$V_0(mV)$	$V_L(mV)$	$R_O=\left(\frac{V_0}{V_1}-1\right)R_L$

Table 4.3

5. Measure input resistance R_i

Connect a sine signal of 1kHz to A point, observe the output by oscilloscope, test A point and B point AC voltage V_s, V_i.

Thus $$R_i=\frac{V_i}{V_s-V_i}\cdot R=\frac{R}{\frac{V_s}{V_i}-1}$$

Tabulate the results in table 4.4.

$V_s(V)$	$V_i(V)$	$R_i = \frac{R}{V_s / V_i - 1}$

Table 4.4

6. Test the follow characteristics of emitter follower and measure peak to peak output voltage V_{opp}.
Connect a sine signal of 1kHz to B point and a load R_L=2K2Ω. Increase the input amplitude gradually, observe the output by oscilloscope. Measure the input voltages V_i and the corresponding undistorted output voltages V_L, test V_i and V_L, calculate A_v and measure the peak to peak output voltages V_{opp}, compare them. Tabulate the results in table 4.5

	1	2	3	4
V_i				
V_L				
V_{opp}				
A_v				

Table 4.5

Experimental report

1. Draw the circuit diagram and mark component parameter.
2. Finish the experimental data, analyze the experimental results. Draw some waveform and curve.
3. Compare the experimental value with the theoretical value, analyze the error.

Experiment 5 Differential Amplifier

Objective

1. To know the working principle of differential amplifier
2. To master the test methods of differential amplifier

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-015(E3)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

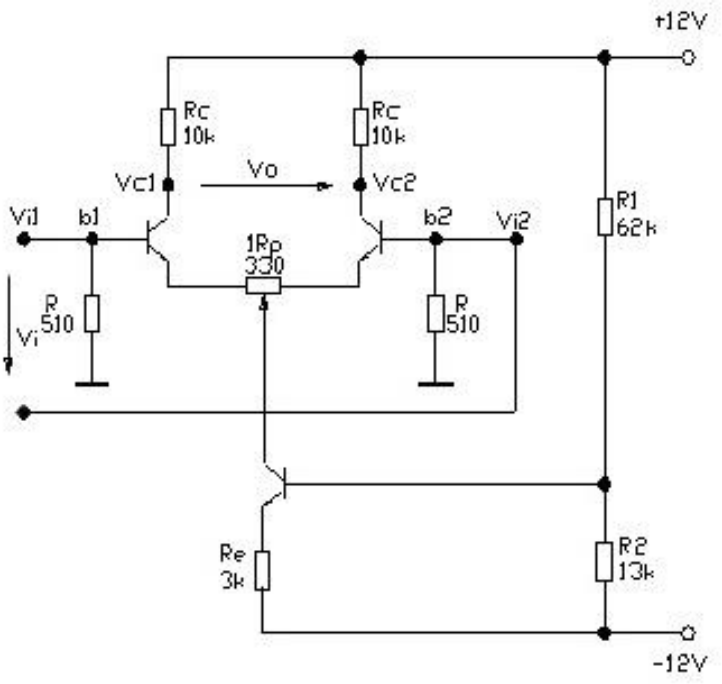

Figure 5.1 Differential amplifier circuit (E3)

1. Test quiescent point

(1) Zeroing

Input short and grounding, adjust R_{P1} to make dual-ended output voltage V_0=0.

(2) Test quiescent point

Measure and tabulate V_l, V_2, V_3 in table 5.1

Voltage to ground	V_{c1}	V_{c2}	V_{c3}	V_{b1}	V_{b2}	V_{b3}	V_{e1}	V_{e2}	V_{e3}
（V）									

Table 5.1

2. Measure differential mode voltage gain

Connect DC voltage $V_{id}=\pm 0.1V$ to inputs, Measure and tabulate Vc_l, Vc_2, V_o in table 5.2 (V_{i1}=+0.1V, V_{i1}=-0.1V).

3. Measure common mode voltage gain

Short b_l, b_2 and connect to a DC voltage, Measure and tabulate Vc_l, Vc_2, V_o in table 5.2 (V_i=+0.1V and -0.1V). Calculate single-ended output voltage gain, dual-ended output voltage gain and common mode rejection ratio CMRR=$\left|\frac{A_d}{A_c}\right|$.

V, A / V_i	differential mode						common mode						
	measure（V）			calculate			measure（V）			calculate			calculate
	V_{c1}	V_{c2}	V_0	A_{d1}	A_{d2}	A_d	V_{c1}	V_{c2}	V_0	A_{c1}	A_{c2}	A_c	CMRR
+0.1V													
-0.1V													

Table 5.2

4. Single-ended input differential amplifier

(1) Ground b_2 and connect DC voltage ± 0.1Vto b_1 (V_i=+0.1V and -0.1V). Measure single-ended output voltage and dual-ended output voltage. Tabulate Vc_l, Vc_2, V_o in table5.3. Calculate the voltage gain and compare with the gain of dual-ended input.

V, A / V_i	V			A	
	V_{c1}	V_{c2}	V_0		
+0.1V					
-0.1V					
Sine（50mV、1kHz)					

Table 5.3

(2)． connect sine signal V_i=50mV， f=1kHz. Measure single-ended output voltage and dual-ended output voltage. Tabulate Vc_l, Vc_2, V_o in table5.3 .Calculate the voltage gain.

Notice: Reduce V_i, if V_{c1}, V_{c2} waveform distortion is observed by oscilloscope.

Experimental report

1. Compare measured quiescent point with theoretical value.
2. Compare each measured and calculated A_d with theoretical value.
3. Summarize the performance and characteristics of differential amplifier.

Experiment 6 Scaling Summing Amplifier

Objective

1. To master the characteristics and performance of scaling summing amplifier
2. To learn the test and analysis method of scaling summing amplifier

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-012(AMP1)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

1. Voltage follower

Circuit as figure 6.1

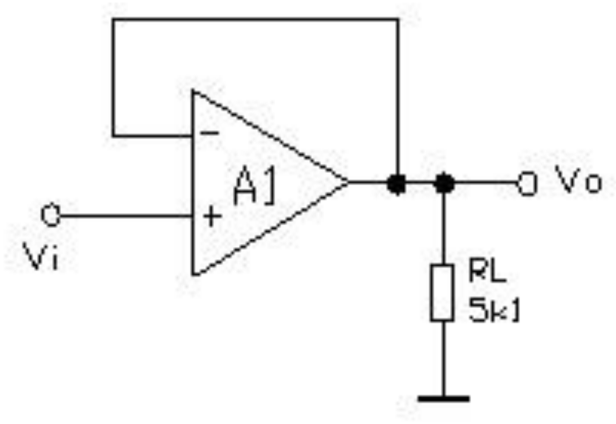

Figure 6.1 Voltage follower circuit (AMP1)

Set the circuit as Figure 6.1, experiment according to table 6.1.

V_i(V)		-2	-0.5	0	+0.5	1
V_0(V)	$R_L=\infty$					
	R_L=5K1					

Table 6.1

2. Inverting scaling amplifier

Circuit as figure 6.2

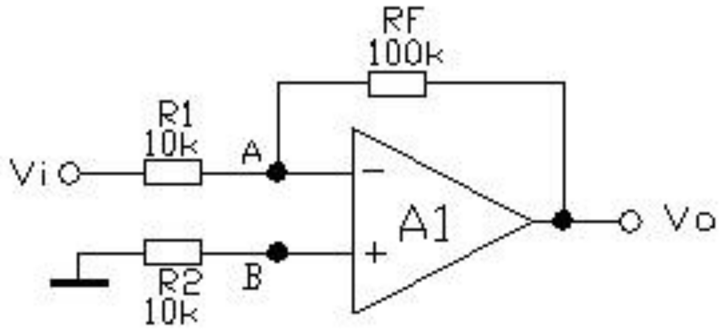

Figure 6.2 Inverting scaling amplifier circuit (AMP1)

(l) Set the circuit as Figure 6.2, experiment according to table 6.2.

V_i（mV）		30	100	300	1000	3000
V_0	calculate（mV）					
	measure（mV）					
	error					

Table 6.2

(2) Experiment according to table 6.3.

	test condition	calculate	measure
$\triangle V_0$	R_L open，V_l 800 mV		
$\triangle V_{AB}$			
$\triangle V_{R2}$			
$\triangle V_{R1}$			
$\triangle V_{0L}$	V_l 800 mV, R_L 5K1		

Table 6.3

(3) Measure f_H upper cut-off frequency of figure 6.2 circuit

3．Non-inverting scaling amplifier

Circuit as figure 6.3

(l) Experiment according to table 6.4 and table 6.5.

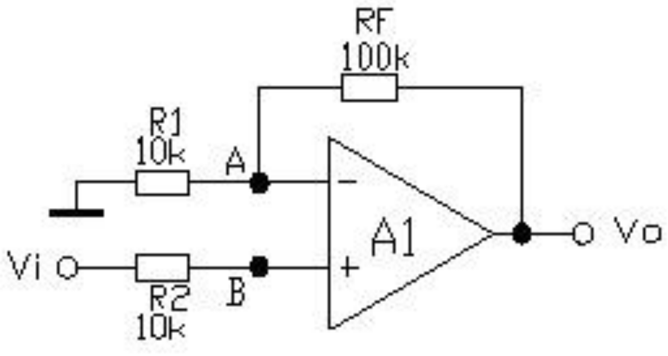

Figure 6.3 Non-inverting scaling amplifier circuit (AMP1)

V_i（mV）		30	100	300	1000
V_0	calculate（mV）				
	measure（mV）				
	error				

Table 6.4

	test condition	calculate	measure
$\triangle V_0$	R_L open，V_l 800 mV		
$\triangle V_{AB}$			
$\triangle V_{R2}$			
$\triangle V_{R1}$			
$\triangle V_{0L}$	V_l 800 mV, R_L 5K1		

Table 6.5

(2) Measure f_H upper cut-off frequency of figure 6.3 circuit.

4．Inverting summing amplifier

Circuit as figure 6.4

Experiment according to table 6.6 and compare with calculate value.

V_{i1}(V)	0.3	-0.3
V_{i2}(V)	0.2	0.2
V_0(V)		

Table 6.6

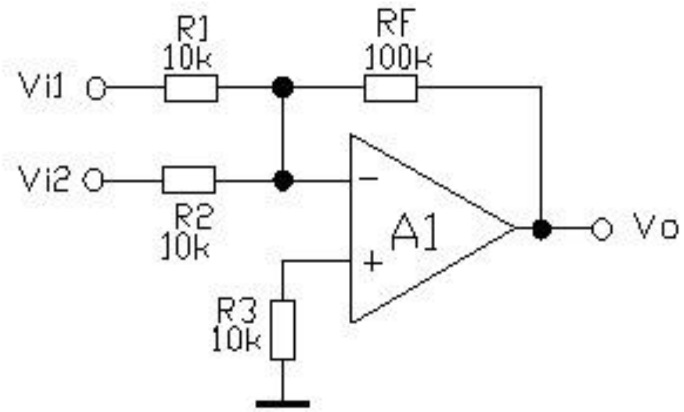

Figure 6.4 Inverting summing amplifier circuit (AMP1)

5．Dual inputs summing amplifier
Circuit as figure 6.5

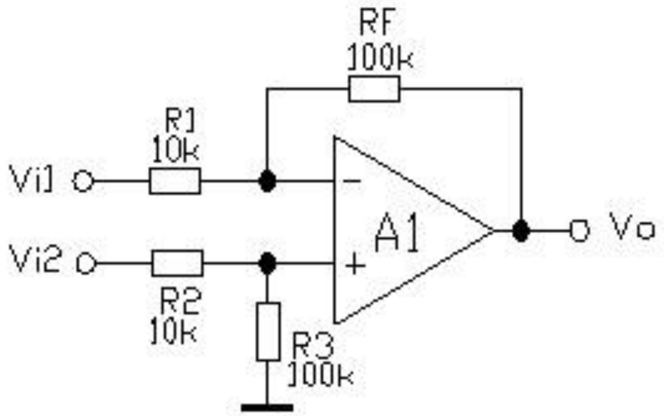

Figure 6.5 Dual inputs summing amplifier circuit (AMP1)

Experiment according to table 6.7

V_{i1}(V)	1	2	0.2
V_{i2}(V)	0.5	1.8	-0.2
V_0(V)			

Table 6.7

Experimental report

1. Summarize the performance and characteristics of 5 amplifier types.
2. Compare the experimental value with the theoretical value, analyze the error.

Experiment 7 Integrator and Differentiator Amplifier

Objective

1. To study to configure integrator and differentiator with operational amplifier.
2. To know the performance and the characteristics of integrator and differentiator amplifier.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-012(AMP1, AMP2)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

1．Integrator

Circuit as figure 7.1.

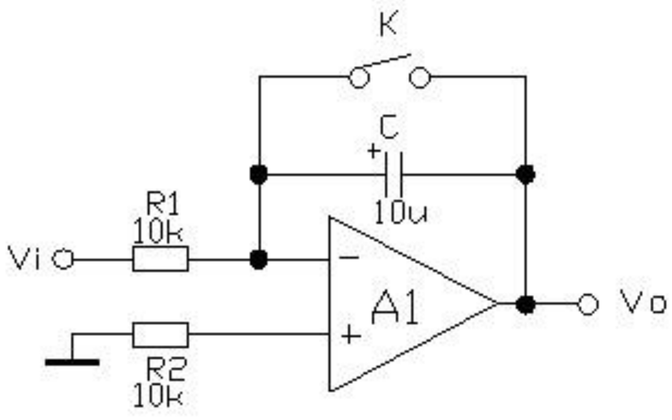

Figure 7.1 integrator (AMP1)

(1) Set V_i＝-1V, open switch K(a jumper wire, pull out a end), observe V_0 with the oscilloscope.

(2) Measure the saturated output voltage and the effective integration time.

(3) Make integration capacitor C to 0.1μF, open switch K, separately input 100Hz, 2V square wave and sine wave to V_i, observe V_0 and V_i , recorder their value, phase and waveform.

(4) Change the frequency, observe the relation of V_0 and V_i in both value and phase.

2．Differentiator

Circuit as figure 7.2.

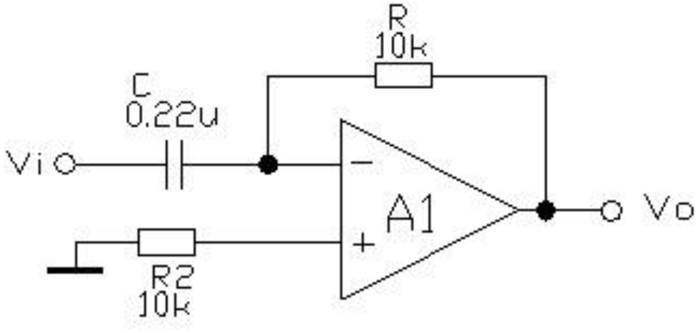

Figure 7.2 differentiator (AMP2)

(1) Input V_i sine, 160Hz, 1V_{RMS}, observe both waveform V_i and V_0 with the oscilloscope, measure V_0.

(2) Change the frequency, observe the change of V_0 and V_i in both value and phase, record them.

(3) Input V_i square wave, f=200Hz, V=±5V, observe V_0 with the oscilloscope, repeat (2).

3．Integrator- Differentiator

Circuit as figure 7.3.

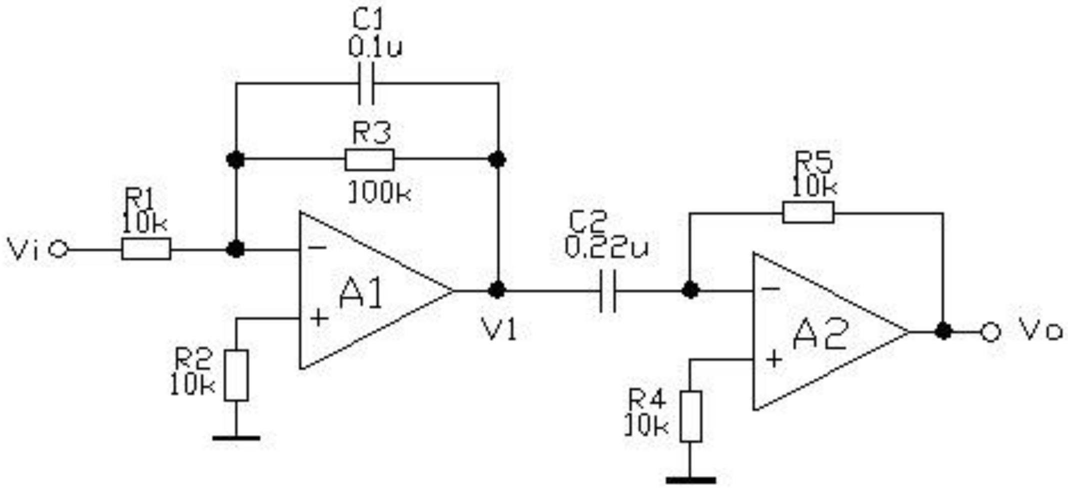

Figure 7.2 integrator-differentiator (AMP1, AMP2)

(1) Input V_i square wave, f=200Hz, V=±6V, observe both waveform V_i and V_0 with the oscilloscope, record them.

(2) Change f=500Hz, repeat (1).

Experimental report

1．Clean up the data in the experiment and the waveform, Summarize the characteristics of integrator and differentiator.

2． Compare the experimental value with the theoretical value, analyze the error.

Experiment 8 Waveform Generator Circuit

Objective

1. To master the characteristics of waveform generator circuit and the analysis method.
2. To know well waveform generator circuit design.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-013(C2, C3, C4, C5)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

1. Square wave generating circuit

Circuit as figure 8.1.

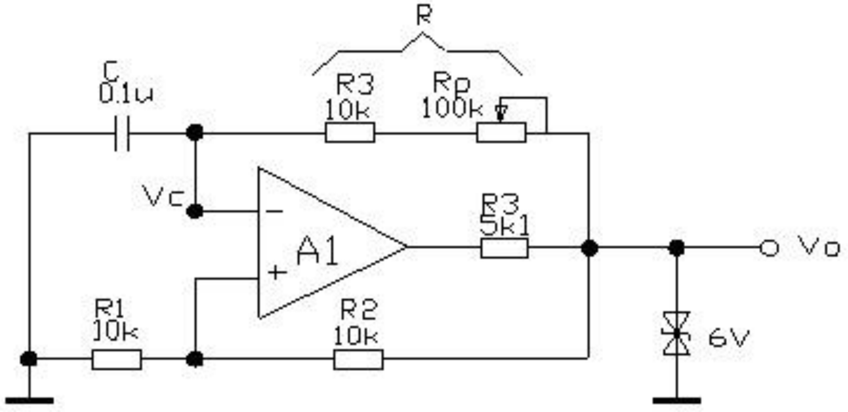

Figure 8.1 square wave generating circuit (C2)

(1) Set up the circuit, observe the waveforms and the frequency of V_C, V_0.
(2) Respectively measure the frequency and the output amplitude at R = 10 KΩ, 110 KΩ.
(3) In order to get a lower frequency, the circuit parameters should be how to choose? Use the components on the circuit board DTS-012 to experiment.
2. Duty cycle adjustable rectangular waveform generating circuit

Circuit as figure 8.2.

(1) Set up the circuit, observe and measure the frequency, the amplitude and the duty cycle.

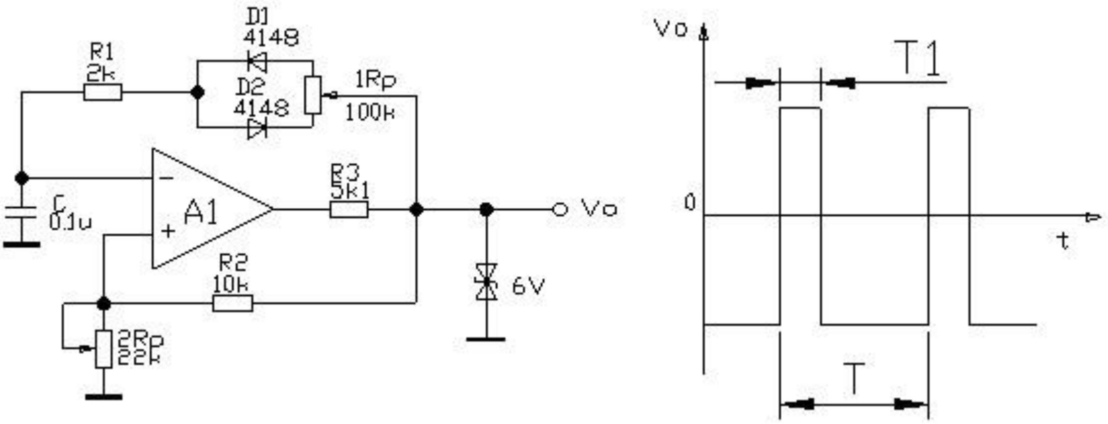

Figure 8.2 rectangular waveform generating circuit (C3)

(2) In order to get a bigger duty cycle, the circuit parameters should be how to choose? Experiment and verify.

3. Triangular waveform generating circuit

Circuit as figure 8.3.

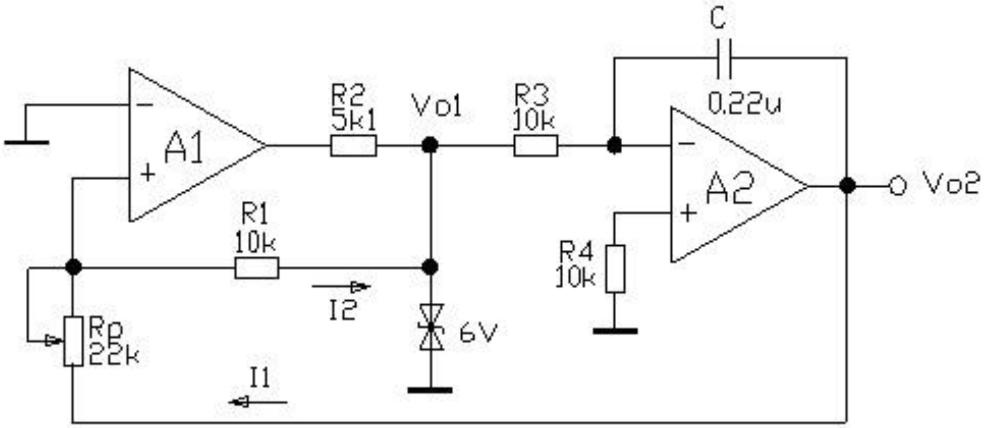

Figure 8.3 triangular waveform generating circuit (C4)

(1) Set up the circuit, observe the waveforms of V_{01}, V_{02} and record them.

(2) How to change the output frequency? Experiment and record.

4. Saw tooth waveform generating circuit

Circuit as figure 8.4.

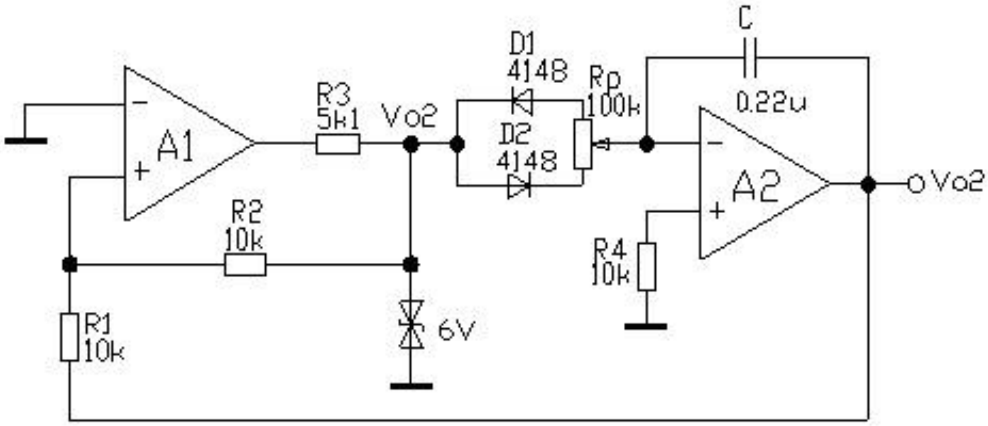

Figure 8.3 saw tooth waveform generating circuit (C4, C5)

(1) Set up the circuit, observe the waveform and the frequency of the circuit.
(2) How to change the saw tooth waveform frequency? Experiment and measure the variation range.

Experimental report

1．Draw all waveforms of the experiments.
2．Draw all circuits of experiment required. Write the experiment steps and the results.
3. Summarizes the characteristics of the waveform generating circuits and answer the questions:
(1) Does waveform generating circuit need to zero adjust？
(2) Do waveform generating circuits have input terminal?

Experiment 9 Active Filter

Objective

1. To know well the configuration and the characteristics of active filter.
2. To study measuring the frequency response of active filter.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-012(AMP1, B2, B3, B4)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

1．Low pass filter

Circuit as figure 9.1, the feedback resister RF is used with 22KΩ potentiometer, setting 5.7KΩ.

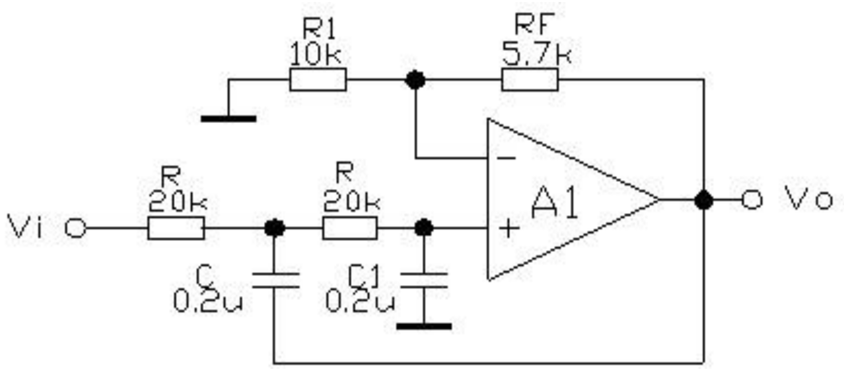

Figure 9.1 low pass filter circuit (AMP1, B2)

Measure and record according to table 9.1.

V_i(V)	1	1	1	1	1	1	1	1	1	1
f(Hz)	5	10	15	30	60	100	150	200	300	400
V_0(V)										

Table 9.1

2．High pass filter

Circuit as figure 9.2.

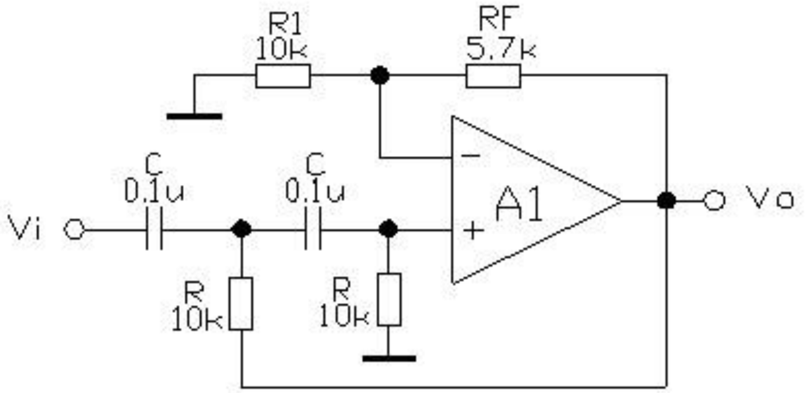

Figure 9.2 high pass filter circuit (AMP1, B3)

Measure and record according to table 9.2.

V_i(V)	1	1	1	1	1	1	1	1	1	1
f(Hz)	5	10	15	30	60	100	150	200	300	400
V_0(V)										

Table 9.2

3．Band rejection filter

Circuit as figure 9.3.

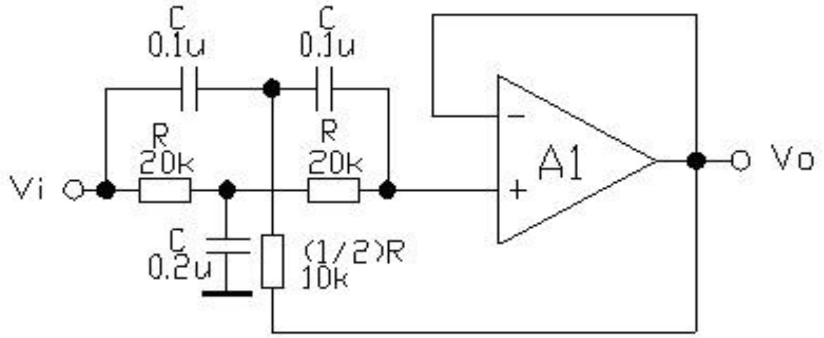

Figure 9.3 band rejection filter (AMP1, B4)

(1) Measure the central frequency of the circuit.

(2) Measuring the frequency response, centered on the measured central frequency.

Experimental report

1. Clean up the data of the experiment and draw each frequency response curve, compare with the precalculated value and analyze the error.

2. How to make band pass filter? Design a band pass filter as 300Hz central frequency.

Experiment 10   Voltage Comparator

Objective

1. To master the configuration and the characteristics of voltage comparator
2. To learn the measure method of voltage comparator.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-012(AMP1, B5, B6)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

1．Zero-crossing comparator

Circuit as figure 10.1.

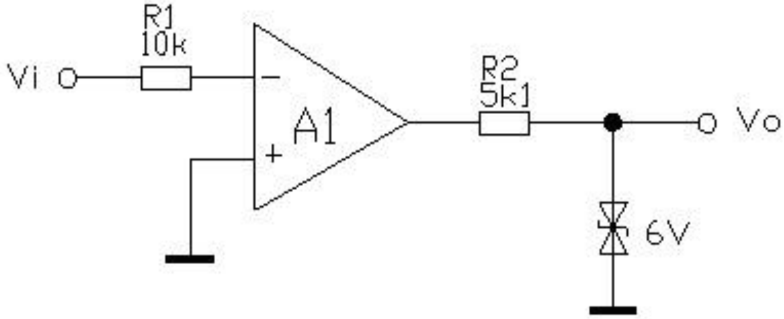

Figure 10.1 zero-crossing comparator (AMP1, B5)

(1) Suspend input V_i, measure the output voltage V_0.

(2) Input V_i with 500Hz,1V_{RMS} sine wave，observe the waveform of V_i,V_0 and record them.

(3) Vary V_i amplitude, observe relevant V_0 variety.

2．Inverting hysteresis comparator

Circuit as figure 10.2.

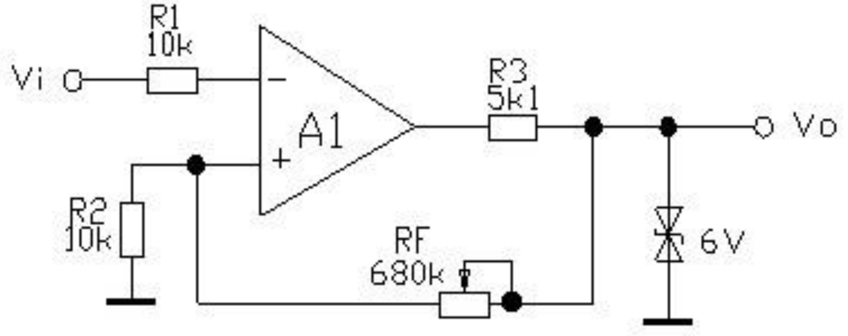

Figure 10.2 inverting hysteresis comparator (AMP1, B5, B6)

(l) Set up the circuit, the feedback resister RF is used with 680KΩ potentiometer, setting 100KΩ, V_i connect to variable DC output of M21-7000, adjust the voltage and record the V_i threshold while output V_0 level jumps from $+V_{om} \rightarrow - V_{om}$.

(2) Same as (l), while output V_0 level switches from $- V_{om} \rightarrow + V_{om}$.

(3) Input V_i with 500Hz,1V_{RMS} sine wave, observe the waveform of V_i,V_0 and record them.

(4) Setting RF 200 KΩ, repeat above experiment.

3. Non-inverting hysteresis comparator

Circuit as figure 10.3.

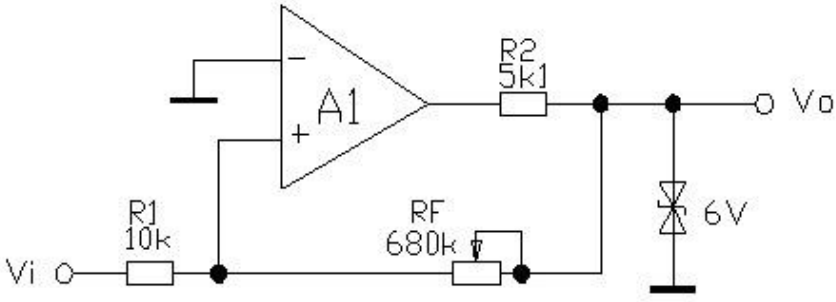

Figure 10.3 non-inverting hysteresis comparator (AMP1, B5, B6)

(l) Refer inverting hysteresis comparator to make your own experimental procedure and method.

(2) Compare the results.

Experimental report

1. Clean up the data and waveforms of the experiment and compare with the precalculated value.
2. Summarizes the characteristics of these comparators.

Experiment 11 Wien Bridge Oscillator

Objective

1. To master the configuration and the principle of Wien bridge oscillator
2. To know the adjustment and measure method of the oscillator.
3. Observe R_C parameter having effect of frequency and learn the measure method of frequency.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-012(AMP1, B2, B3)
3. Oscilloscope
4. Frequency counter

Experimental procedure

1. Set up the circuit as figure 11.2, presetting $1R_p$=Rl=10KΩ.
2. Observe the output waveform with the oscilloscope.

Thinking:

(1) If all are in correct, but V_0=0, what is the cause and what's to be done?

(2) If the output distortion is observed, what's to be done?

3. Measure the frequency f_{01} with frequency counter or Lissajous method as figure 11.2 and compare with calculated value.

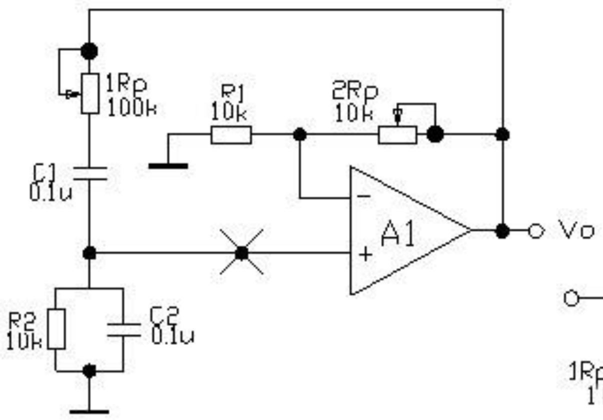

Figure 11.1 Wien bridge oscillator (AMP1, B2, B3)

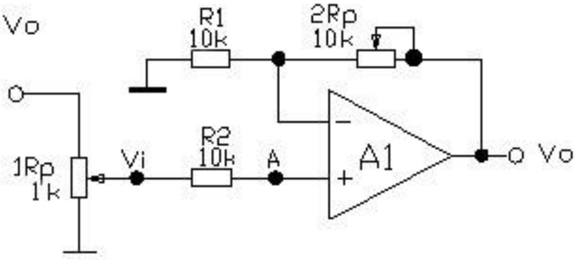

Figure 11.3 (AMP1, B2, B3)

4．Change the oscillation frequency

Presetting Wien bridge resistor R =10K+20K(first setting $1R_p$=30K, then R1 being joined into another 20K resistor).

Notice: Before change parameter of the resisters, disconnect the power source. Before f_0 measure, adjust $2R_p$ and V_0 for distortionless.

5．Measure the closed-loop voltage gain of the operational amplifier A_{Uf}.

Measure the output voltage V_0. Disconnect the power source, maintain $2R_p$ and the oscillation frequency. Disconnect A point from RC Wien Bridge network and connect to the function generator through 1KΩ potentiometer and 10KΩ resister as figure 11.3. Adjust V_i to make V_0 equal to the original value, measure V_i.

Thus: $A_{Uf}=V_0/V_i=$__

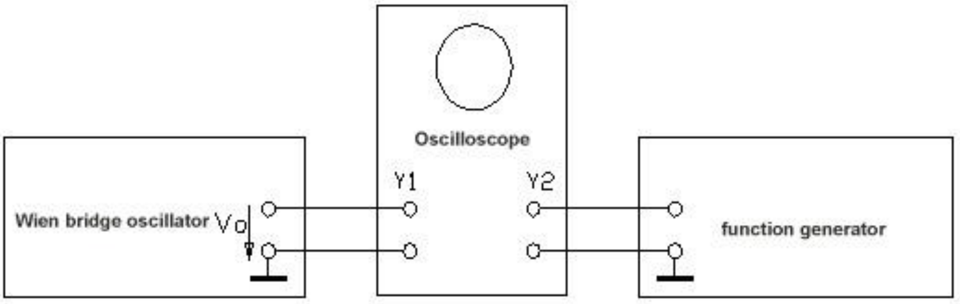

Figure 11.2

6．Propose detailed steps to measure the frequency response curve of RC Wien bridge circuit.

Experimental report

1. What parameters in the circuit are related with the oscillation frequency? Compare the measured frequency with theoretical value, analysis the causes.

2. Summarize negative feedback depth having effect of the start-oscillation condition and output waveform.

3．Complete following summary:

(1) The constituent part of the positive feedback circuit ________.

(2) The network has ________ character.

(3) Change ________ or _______ to change oscillation frequency.

(4) 1Rp and R1 consist _________ feedback, _______ for adjusting the gain of the amplifier to make $A_u \geq 3$. 6．Propose detailed steps to measure the frequency response curve of RC Wien bridge circuit.

4．Draw the frequency response curve of RC Wien bridge circuit.

Experiment 12 Integrated Power Amplifier

Objective

1. To know the performance of integrated power amplifier
2. To master the characteristics of integrated power amplifier and the measure method.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-015(E2)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

1. Set the circuit as figure 12.1, measure static working current.

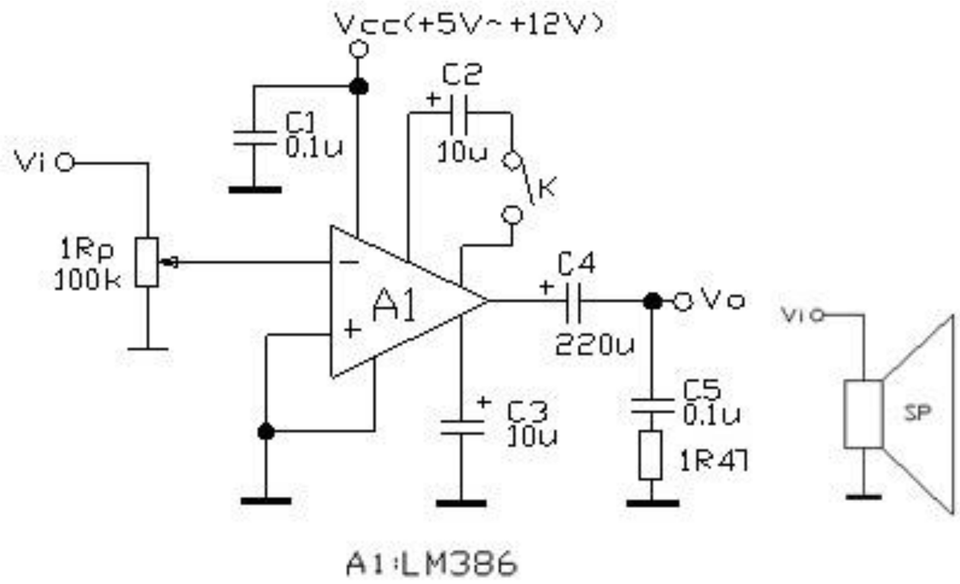

Figure 12.1 integrated power amplifier (E2)

2. Input V_i with 1KHz sine wave，observe the waveform of V_0 and gradually increase V_i until V_0 is distorted, record the amplitude of V_i and V_0, also waveforms.

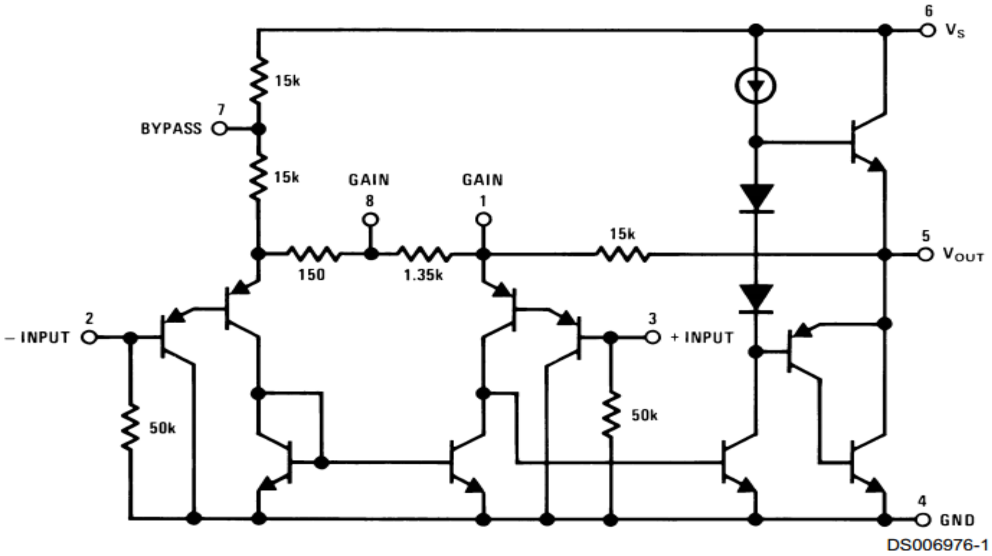

Figure 12.2 LM386 equivalent schematic

3. Remove C_2 10μF, repeat procedure 2.
4. Alter power supply voltage V_{cc}（5V or 9V）, repeat procedure 2 and 3.

Experimental report

1. According to the experimental measurements, calculate P_{OM}、P_V and η in various circumstances
2. Make the power supply voltage, output voltage and output power curve relation.

Experiment 13 Rectifier Filter and Parallel Regulation Circuit

Objective

1. To know well half wave rectifier, full wave rectifier and full wave bridge rectifier
2. To observe the effect of capacitor filtering
3. To know the parallel regulation circuit

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-016(F1, F5)
3. Oscilloscope
4. Digital multimeter
5. Variac

Experimental procedure

1. Set up half wave rectifier circuit and full wave bridge rectifier circuit as figure 13.1, figure 13.2. The variac outputs 10V.

Obverse V_2 and V_L of both circuits by oscilloscope, measure V_2, V_D, V_L.

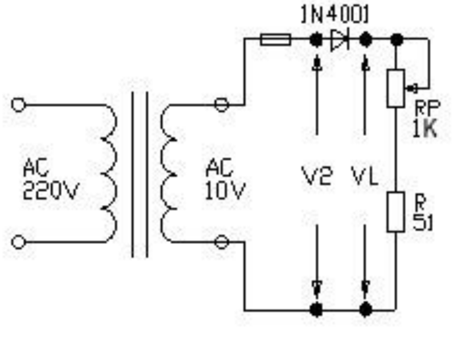

Figure 13.1 (F1)

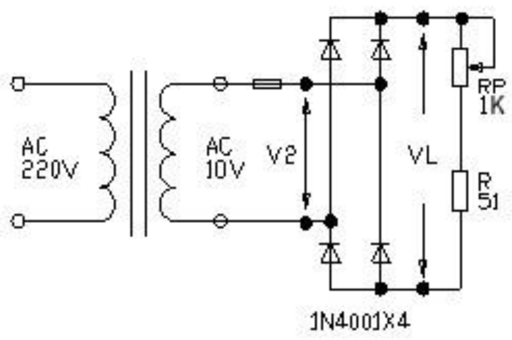

Figure 13.2 (F1)

2．Capacitor filter circuit

Set up the circuit as figure 13.3

(1) Connect different capacitor, but disconnect R_L, obverse V_L waveform by oscilloscope and measure the value with multimeter. Then record.

(2) Connect R_L=1KΩ, repeat (1).

(3) Alter R_L=150Ω, repeat (1).

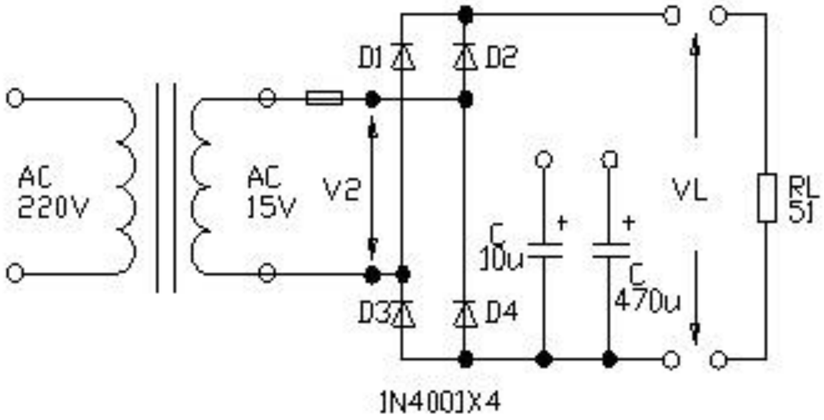

Figure 13.3 (F1)

3．Parallel regulation circuit

Set up the circuit as figure 13.4

(1) The voltage stability when the power input voltage is constant, while the load is changed.

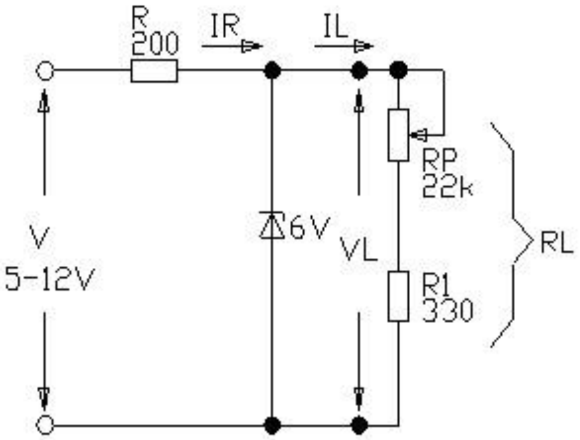

Figure 13.4 (F1, F5)

Change R_L make load current I_L =l mA，5mA，10mA , respectively measure V_L, V_R, I_L, I_R， calculate output resistance.

(2) The voltage stability when the load is constant, while the power input voltage is changed.

Adjust the power input voltage to 10V, then 8V, 9V, 11V, 12V gradually， measure and complete table 13.1, calculate regulation factor.

V_1	$V_L(V)$	$I_R(mA)$	$I_L(mA)$
10			
8V			
9V			
11V			
12V			

Table 13.1

Experimental report

1. Clean up the experimental data and finish the relevant calculation.
2. What is the maximum current of the parallel regulation circuit (figure 13.4)? How to select components and parameters for bigger current?

Experiment 14 Series Regulation Circuit

Objective

1. To study the character of regulated power supply, master the working principle of series voltage regulator
2. To learn the debugging and measuring method of regulated power supply

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-016(F2, F1)
3. Oscilloscope
4. Digital multimeter
5. DC power supply
6. Transformer

Experimental procedure

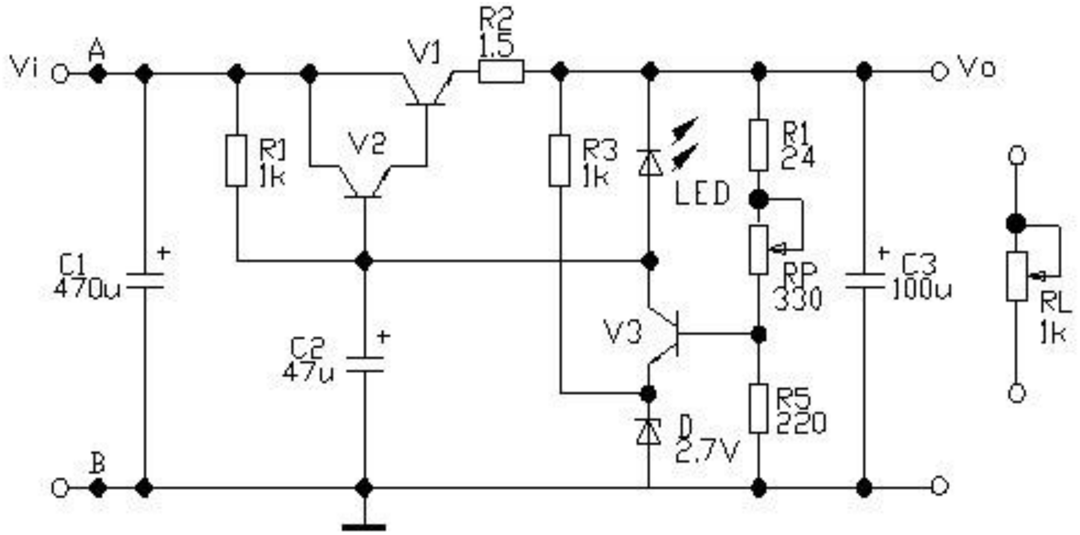

Figure 14.1 series regulation circuit (F2)

1. Static debug

(1) Find out all related components on circuit board DTS-016 and check their terminals.

(2) Set the circuit as figure 14.1，open the load R_L, means the regulated power supply is no load.

(3) Set DC power supply 9V and connect to V_i terminal, adjusting R_p lead to V_0=6V.

Test Q points of all transistors.

(4) Adjust the output voltage regulation range

Adjust R_P and observe the change of output voltage $V_{0,}$ record the maximum and the minimum.

2．Dynamic measurement

(1) Measure power supply regulation characteristic.

Remain the regulated power supply no load, adjust DC power supply output voltage to simulate mains voltage fluctuating ±10%, V_i from 8V to 10V. Measure the corresponding delta △V.

Calculate voltage stability factor (line regulation) $S=\frac{\Delta V_0/V_0}{\Delta V_1/V_1}$

(2) Measure power supply internal resistance.

Connect load R_L and adjust it to get output current I_L=100mA, measure the variation of output voltage $V_{0,}$ find out power supply internal resistance $\left| r_0 = \frac{\Delta V_0}{\Delta I_L} \times 100\% \right|$. During the measurement remain V_i＝9V.

(3) Measure power supply ripple voltage.

Set up rectifier and filter circuit as Figure 14.1 and connect the output to the regulated power supply input V_i. At I_L=100mA, observe the alternating component u_0 of the regulated power supply output by oscilloscope, draw the waveform. Measure the ripple with digital multimeter AC function or millivoltmeter.

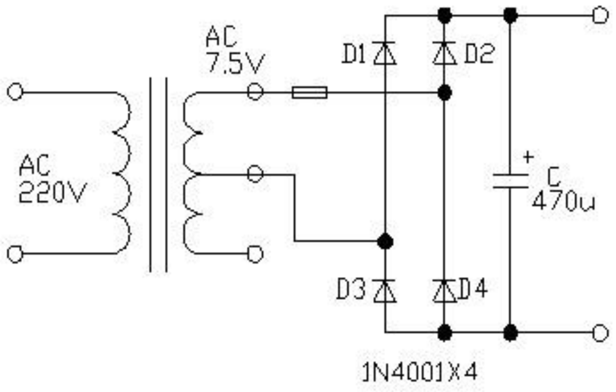

Figure 14.2 (F1)

Discussion：

A：In figure 14.1, if adjusting R_p, how will Q points of all transistors be changed?

B：Adjusting R_L, how will the V_3 emitter level be changed? How will be V_0?

C: Remove C3 (open it), how will be the output voltage?

D：In the regulated power supply, which transistor is the largest power-consume one?

3. Output protection

(1) Check the output current and voltage with multimeters. Gradually reduce R_L value until short circuit and LED luminesce, record the current and voltage.

(2) Gradually increase R_L value，observe and record the current and voltage. Note that, short circuit time should be in 5 sec. to avoid components over heat.

Discussion：

How to change the regulated power supply protection parameter

Experimental report

1. Summarize the static debug and the dynamic measurement.
2. Calculate the regulated power supply internal resistance $r_0=\frac{\Delta V_0}{\Delta I_L}$ and stability factor S_r.
3. Write out some results of the discussion.

.

Experiment 15 Integrated Voltage Regulator

Objective

1. To know the character of integrated voltage regulator and the method of application
2. To master the main parameter test method of DC regulated power supply

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-016(F3, F4)
3. Oscilloscope
4. Digital multimeter
5. DC power supply

Experimental procedure

1．Integrated voltage regulator measure

Set up the circuit as figure 15.1

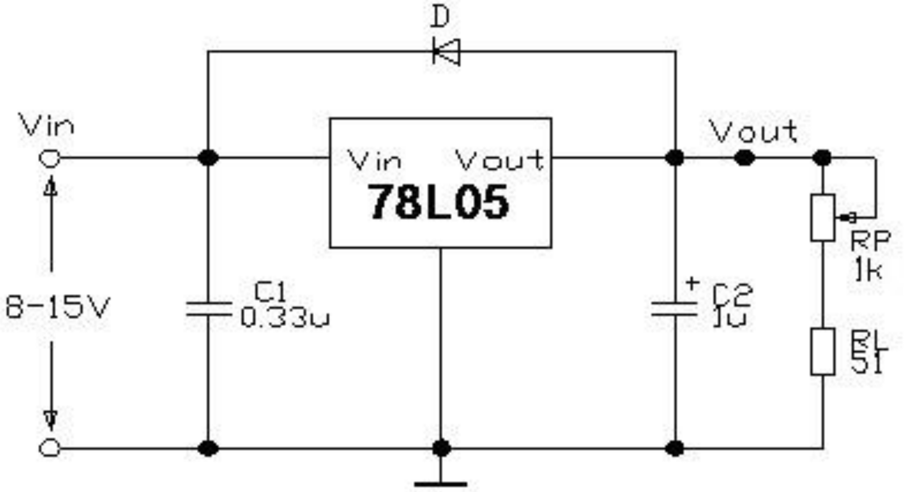

Figure 15.1 (F3)

Measure parameter:

(1) Output voltage

(2) Voltage regulation

(3) Current regulation

(4) Ripple voltage（RMS or Peak to Peak）

Measure performance:

(1) Minimal input voltage for maintaining a stable output voltage.

(2) Maximal output current and over current protection.

2. Integrated voltage regulator application

(1) Adjust output voltage

Set up the circuits as figure 15.2 and 15.3, measure the output voltage and the adjustable range.

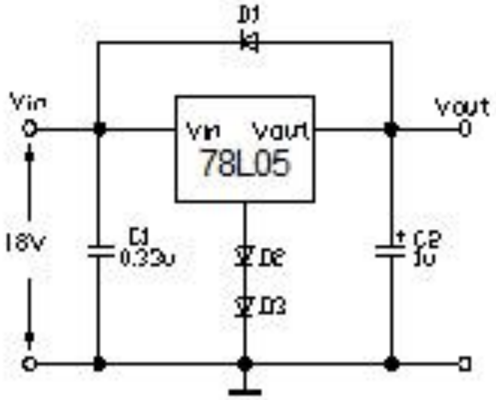

Figure 15.2 (F3)

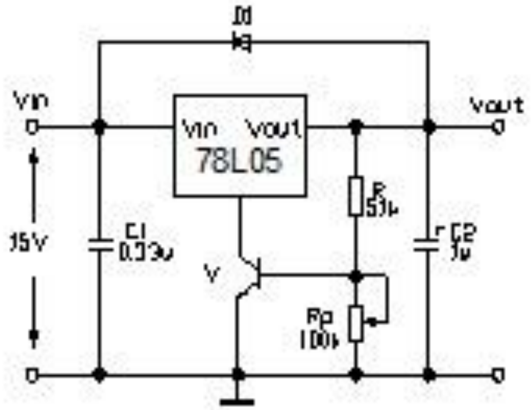

Figure 15.3 (F3)

(2) Form a constant current power supply

Set up the circuits as figure 15.4, test the constant current function.

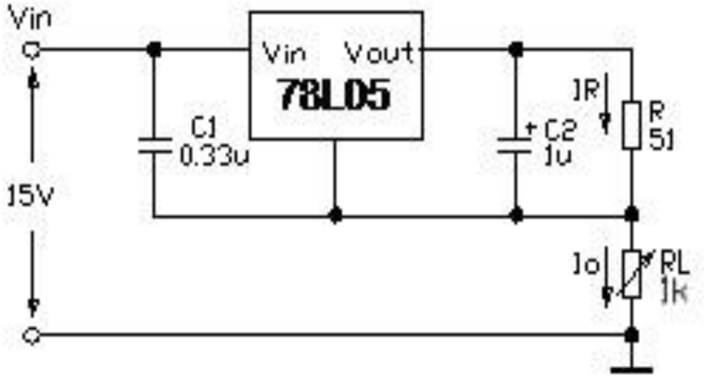

Figure15.4 (F3)

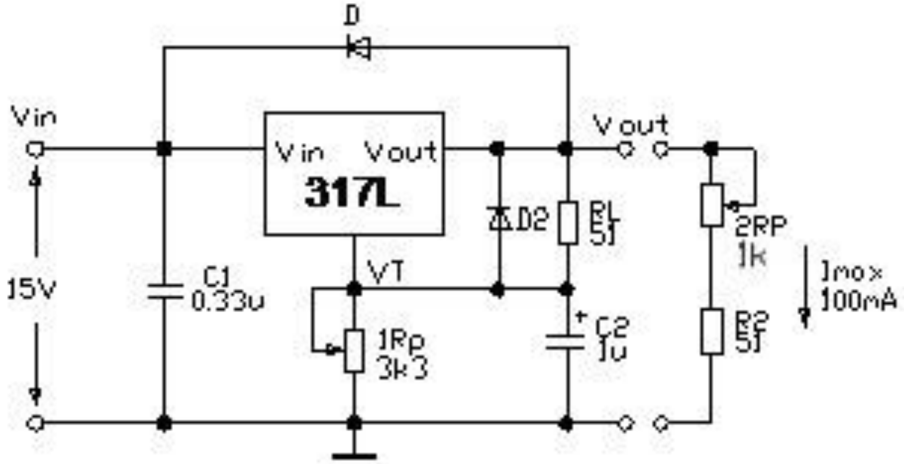

Figure 15.5 (F4)

(3) Adjustable integrated voltage regulator
Maximum input voltage of LM317L is 40 v, output voltage 1.25V ~37V, maximum output current 100mA. Here set the input voltage as 15V.
Set up the circuits as figure 15.5 and measure:
a. Output voltage range.
b. Adjust output voltage up to maximum, measure all parameters same as experimental procedure 1.

Experimental report

1． Clean up the data in the experiment, calculate and get all parameters in experimental procedure 1.

2． According to experimental procedure 2, draw out the output protection character curve.

3． Summarize the application method of these two integrated voltage regulators

Experiment 16 RC Oscillator

Objective

1. To know the composition and principle of double T network oscillator
2. To learn debugging and measuring method of oscillator

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-014(D4)
3. Oscilloscope

Experimental procedure

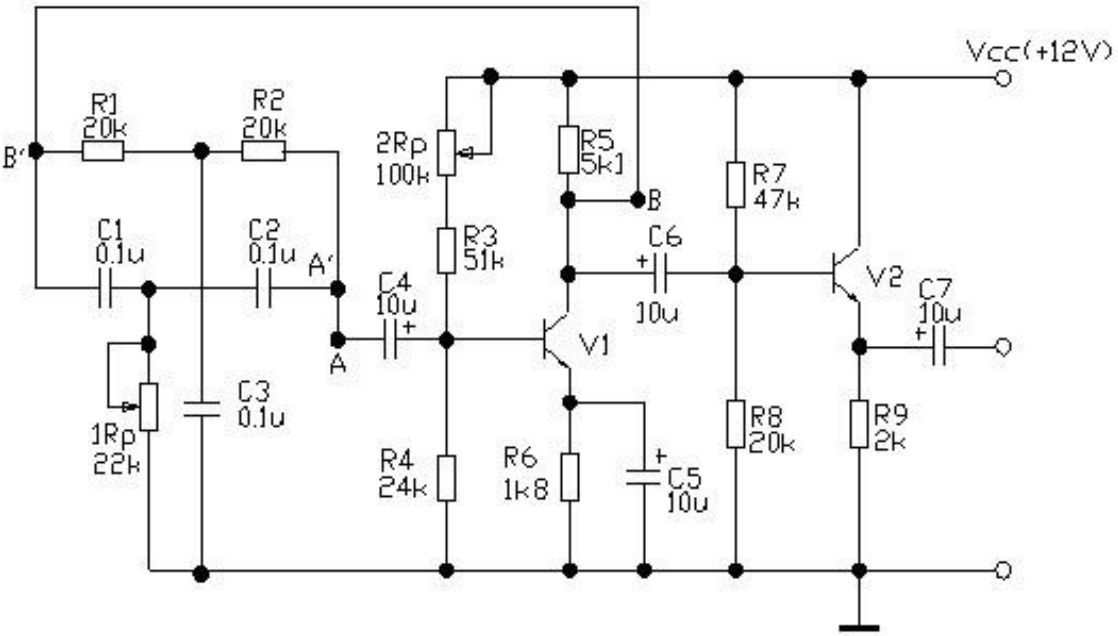

Figure 16.1 RC oscillator (D4)

1. Set up the circuit as figure 16.1, but do not connect double T network（A, B are disconnected to A', B'）, adjust V1 static point and make B point voltage 7~8V.
2. Connect double T network into the circuit, observe output waveform with oscilloscope. If no oscillation, adjust R_P. to be so.
3. Measure the frequency with oscilloscope and compare with the theoretical value.
4. Adjust $1R_P$ from small to large and observe output waveform. Measure the $1R_P$ value,

with it the circuit starts to oscillate.
5. Disconnect double T network from the circuit, then input a sine signal into B' point and observe output waveform at A' point. Maintain the amplitude of the input signal while change the frequency from low to high, then get the output signal frequency with the smallest amplitude.

Experimental report

1． Clean up the data and waveform in the experiment.
2. Answer questions:
(l) What kind of feedback the figure 16.1 circuit is?
(2) What effect does R_P have in the circuit?
(3) Why should the circuit be followed an emitter follower?

Experiment 17 LC Oscillator and Frequency-Selective Amplifier

Objective

1. To study the character of LC sine oscillator
2. To study the amplitude-frequency characteristics of LC frequency-selective amplifier

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-014(D3)
3. Oscilloscope
4. Counter

Experimental procedure

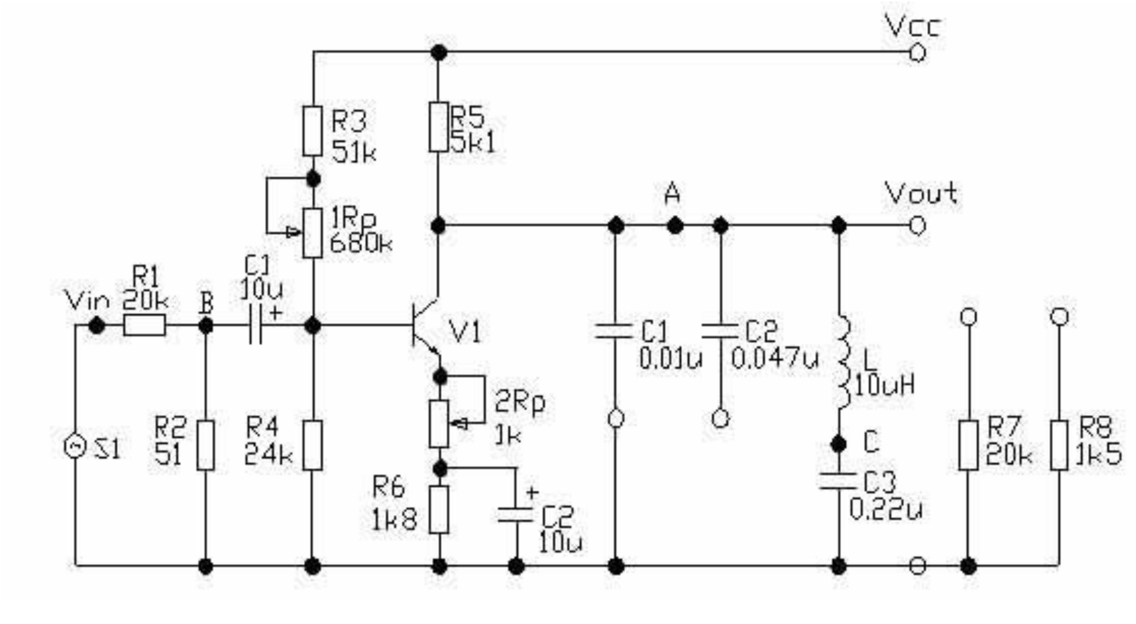

Figure 17.1 LC oscillator and frequency-selective amplifier (D3)

1. Amplitude-frequency characteristics chart of LC frequency-selective amplifier

(l) Set up the circuit as figure 17.1, capacitor C selected 0.01μF first.

(2) Adjust $1R_P$ to make transistor V_1 collector voltage 6V ($2R_P = 0$).

(3) Input a sine signal into V_{in}, adjust amplitude and frequency to get f=16KHz, V_{in}=l0$v_{P\text{-}P}$. Observe the output waveform with oscilloscope, adjust $2R_P$ to get minimum

distortion and maximum amplitude. Measure the amplitude and calculate the gain A_u.
(4) Fine-tune input frequency (amplitude fixed) to get maximum V_{out}, record the both resonant frequency f_0 and amplitude.
(5) Change input frequency as f_0-2KHz, f_0-1KHz, f_0-0.5KHz, f_0+0.5KHz, f_0+1KHz, f_0+2KHz, measure respectively corresponding output amplitude.
(6) Alter capacitor C to 0.047μF, repeat above procedure.
2. Study LC oscillator
In figure 17.1, disconnect input signal, join up C=0.01μF, remove R_2.
In the case of not connect two points B and C, Adjust $1R_P$ to make transistor V_1 collector voltage 6V ($2R_P$＝0).
(1) Oscillation frequency
a. Connect two points B and C, observe A point waveform with oscilloscope, measure the frequency and compare with the resonant frequency of the frequency-selective amplifier.
b. Alter capacitor C to 0.047μF, repeat above procedure.
(2) Oscillation amplitude condition
a. On the basis of the above form stable oscillation, measure V_b、V_c、V_a , calculate $A_u F$ and confirm it equal to 1.
b. Adjust $2R_P$ to increase the negative feedback, observe if the oscillation would stop.
c. In the case of recovery oscillation, respectively join up load resistor 20K、1K5 at point A, observe the changes of output waveform.
3. Factors affecting the output waveform
(l) Under the condition of no output waveform distortion, adjust $2R_P \rightarrow 0$ to reduce the negative feedback, observe the changes of oscillation waveform.
(2) Adjust $1R_P$ to recover no distortion, then adjust $2R_P$ and observe the changes of oscillation waveform.

Experimental report

1．According to the experimental procedure 1, draw the frequency-selective curve $|A_u|$~f .
2. Record the experimental phenomena in procedure 2, then explain reasons.
3. Summarize the negative feedback effect to the oscillation amplitude and waveform.
4. Analysis the oscillation condition and the waveform under the influence of static working point.

Experiment 18 Current/voltage Conversion Circuit

Principle

In industrial control, need to convert 4 mA ~ 20 mA current signal into ±10V voltage signal, so that send to computer for processing. The conversion circuit is 4mA for 0% scale corresponding to -10V, 12mA for 50% scale corresponding to 0 V and 20 mA for 100% scale corresponding to +10 V. The reference circuit as shown in figure 18.1

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-014(AMP7, AMP8)
3. Digital multimeter

Experimental procedure

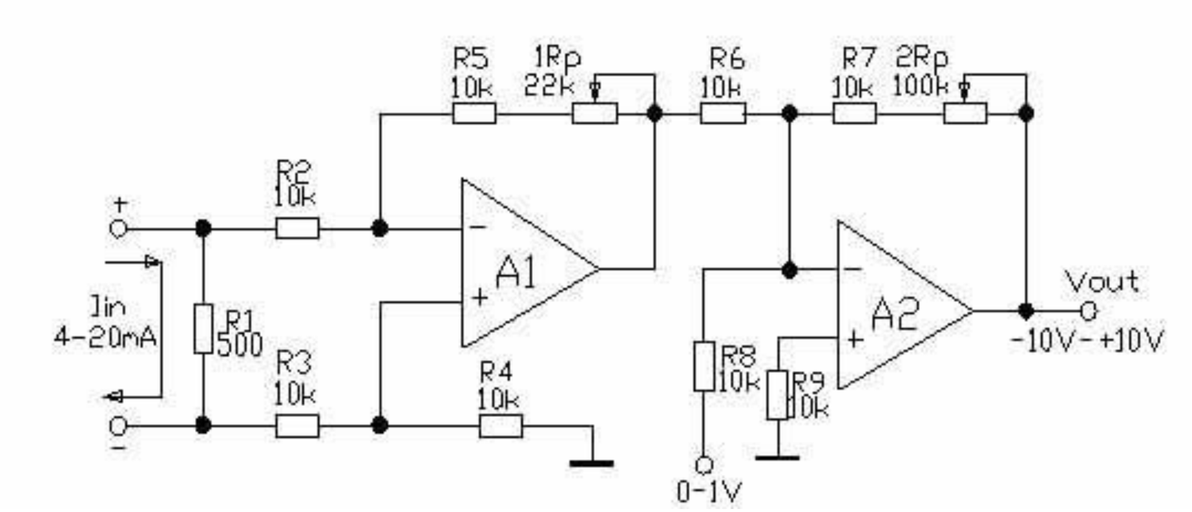

Figure 18.1 current/voltage conversion circuit (AMP7, AMP8)

1. Set up the circuit of constant current source as figure 15.4, adjust R value to match output current 4~20mA.
2. Set up the circuit as figure 18.1, adjust $1R_P$ and $2R_P$ to match output voltage from -10V to +10 V.

Choose to do and think

1. Can the circuit be changed to a voltage/current conversion circuit? Think and make a circuit diagram.

2. Follow the think, design a voltage/current conversion circuit to convert ±10V voltage signal into 4mA ~ 20mA current signal.

Experiment 19 Voltage/frequency Conversion Circuit

Principle

Experimental circuit as shown in figure 19.1, the diagram is actually a saw tooth wave generating circuit, but here is by changing the input voltage Vi to change the frequency, thus a voltage parameter is transformed into a frequency parameter.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-014(AMP7, AMP8, D1)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

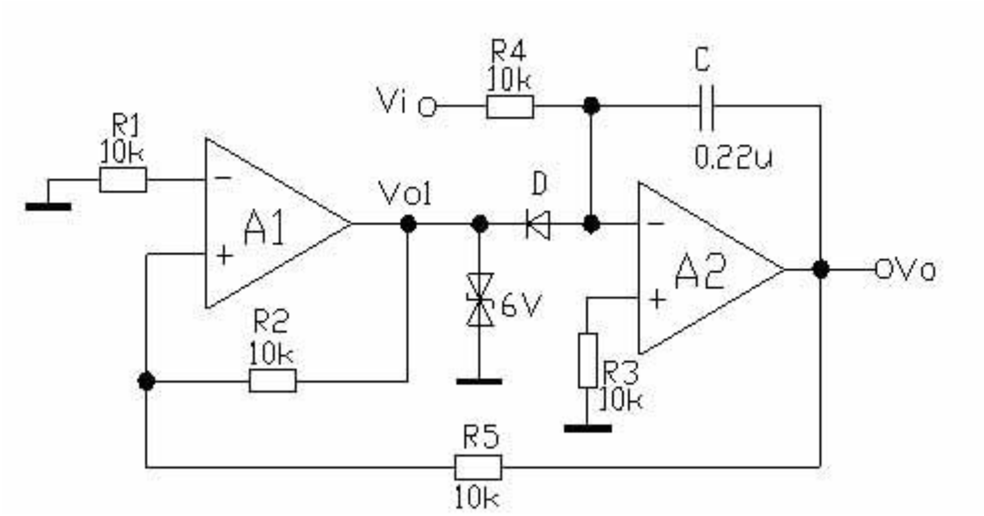

Figure 19.1 voltage/frequency conversion circuit (AMP7, AMP8, D1)

Set up the voltage/frequency conversion circuit as figure 19.1, observe the output waveform V_0.

According table 19.1， measure the voltage - frequency conversion relations. Measure the period with oscilloscope and then converted to frequency.

V_i(V)	0	1	2	3	4	5
T(ms)						
f(Hz)						

Table 19.1

Experimental report

1. Indicate the charging and discharging loop of capacitor C in figure 19.1.
2. Analyze the working principle of adjusting V_i voltage to change V_0 frequency.
3. How do you determine the resistance of R4 and R5? When output signal amplitude is $12V_{p-p}$, the input voltage is 3V, the output frequency is 3000Hz, calculate R4, R5 values.
4. Draw the curve of frequency/voltage.

Experiment 20 Complementary Symmetry Power Amplifier

Objective

1. To know the composition of a complementary symmetry power amplifier
2. To learn how to measure output power and efficiency of power amplifier

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-015(E1)
3. Oscilloscope

Experimental content

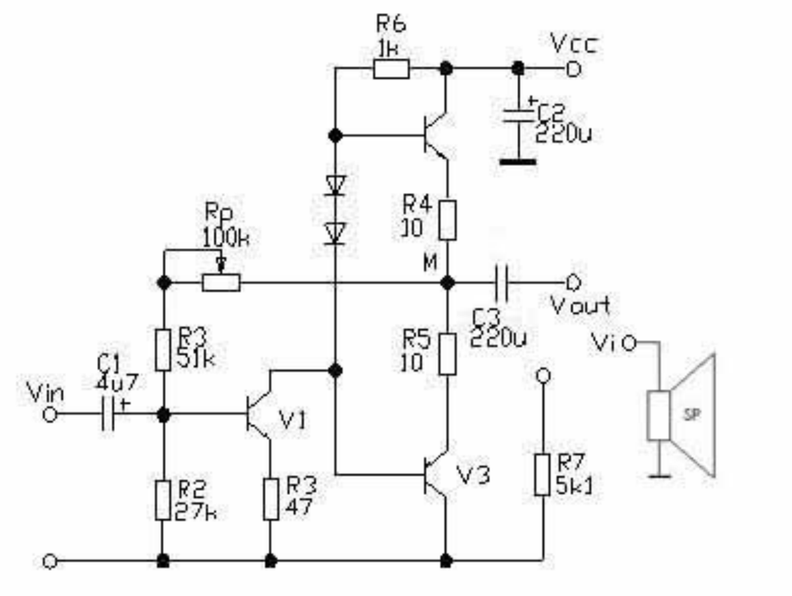

Figure 20.1 complementary symmetry power amplifier circuit (E1)

1. Set up the complementary symmetry power amplifier circuit as figure 20.1, adjust dc working point, and make M point voltage equal 0.5 Vcc.
2. Measure maximum distortionless output power and efficiency
3. Vary the power supply voltage (for example, alter +10V to + 6V) l2V, measure and compare the output power and efficiency.

4． Compare the output power and efficiency of the complementary symmetry power amplifier with the loads 5.1KΩ and 8Ω (speaker).

Experimental report

1． Analysis the working state of each transistor and the crossover distortion in the circuit.

2． If do not add input signal, how much is the power consumption of V2, V3 transistors?

3. What is the role of the resistor R4, R5?

4. According to the experimental content draw up the experimental procedure and record form.

5. Analysis of the experimental results, calculate the parameters under experimental content required.

6. Summarizes the characteristics of power amplifier circuit and measuring method.

Experiment 21 Waveform Conversion Circuit

Objective

1. To be familiar with the working principle and characteristics of waveform conversion circuit
2. To master the circuit parameter selection and the circuit adjusting methods.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-012(AMP1, B6), DTS-014(AMP7, AMP8)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

1. Square wave to triangle wave

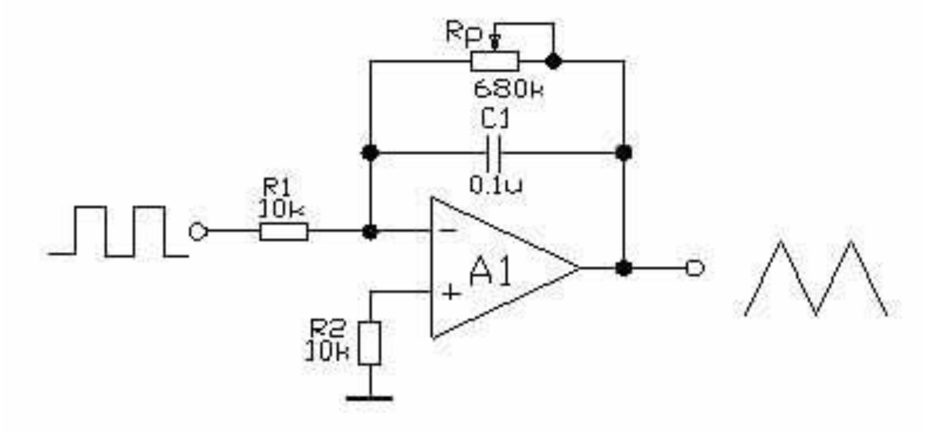

Figure 21.1 (AMP1, B6)

(1) Set up the circuit as figure 21.1, add a square wave signal, frequency=500Hz, amplitude= $\pm$4V. Observe and record the wave form of output.
(2) Change the square wave signal frequency, observe the variation of the triangle wave.
If the wave form is distorted, how do you adjust the circuit parameter for recover? Do it and check the result.
(3) Change the square wave signal amplitude, observe the variation of the triangle wave.

2. Precision rectifier circuit

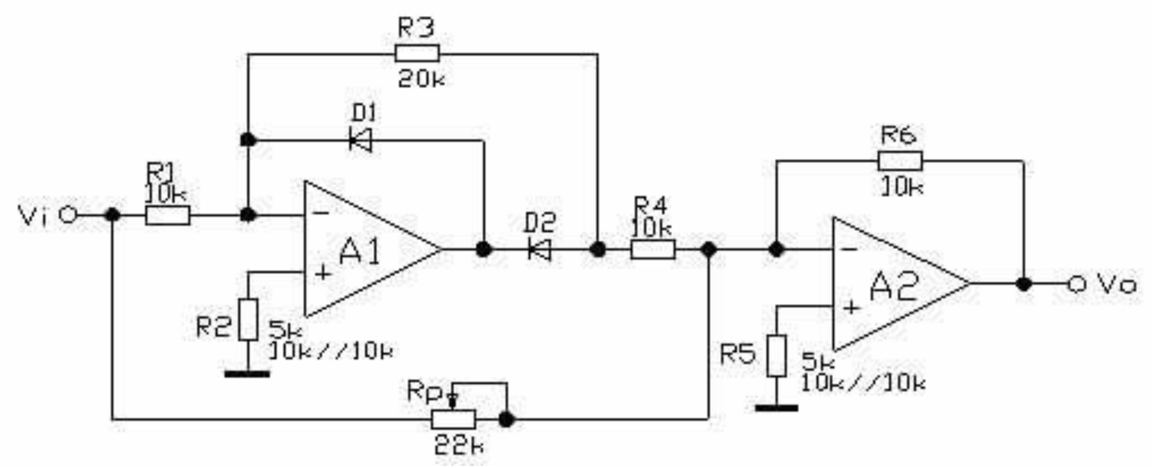

Figure 21.2 (AMP7, AMP8)

(1) Set up the circuit as figure 21.2, add a sine wave signal, frequency=500Hz, amplitude= $1V_{RMS}$. Observe and record the wave form of output.
(2) Change the sine wave signal amplitude and frequency (at least three set), observe the wave form of output.
(3) Alter sine wave into triangle wave, repeat the above procedure.
3. Sine wave to square wave conversion circuit design
(l) The required amplitude is ±6 V, frequency is same as sine wave.
(2) Design the circuit and set up. Add a sine wave signal, frequency=500Hz, amplitude= $4V_{RMS}$. Observe the wave form of output and compare with the requirement.
(3) Change the sine wave signal amplitude and frequency, repeat above procedure. Observe whether the input and output signal phase is consistent.

Experimental report

1. Analysis the working principle of the circuit in figure 21.1, what is the working frequency requirement of the conversion circuit?
2. Drew the wave form of V_a and V_o of the circuit in figure 21.2.
3. Design the sine wave to square wave conversion circuit as required in step3.
4. Draw up all experimental procedure and record form.
5. Summarizes the characteristics of waveform conversion circuit.

Experiment 22 FET Amplifier

Objective

1. To master FET output characteristics, transfer characteristics, main performance parameters and test methods.
2. To learn FET amplifier circuit design methods.

Experimental device

1. Digital-analog training system M21-7000
2. Circuit board DTS-015(E4)
3. Oscilloscope
4. Digital multimeter

Experimental procedure

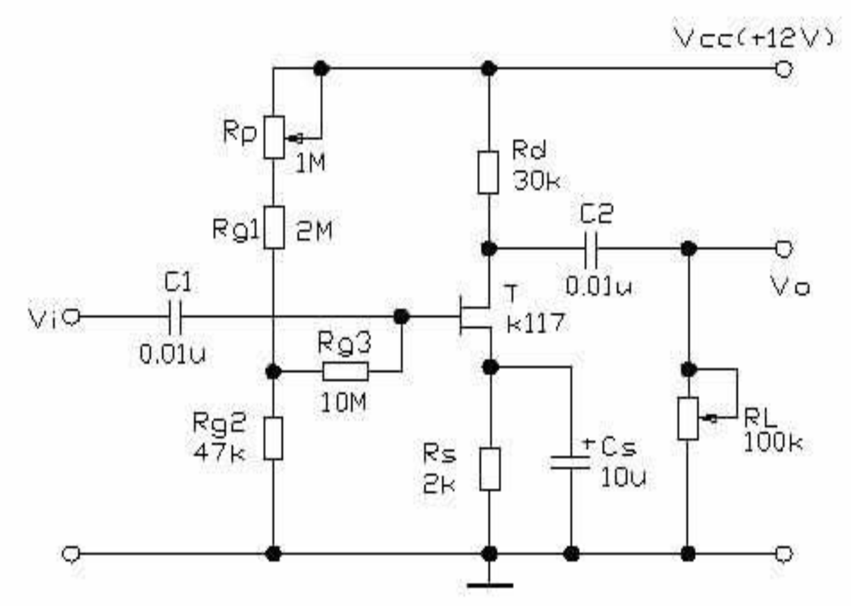

Figure 22.1 FET amplifier circuit (E4)

1. Static adjustment

(1) Set up the circuit as figure 22.1, first disconnect R_p as a self-bias circuit.

(2) Check and confirm right connection, then +12V power on.

(3) Measure the voltages V_g, V_s, V_d. Connect R_p to the circuit and redo the measurement with varied R_p, tabulate.

Measure value				Calculate value	
Rp	Vg	Vs	Vd	I_g(μA)	I_d(mA)
Disconnect(self-bias)					
R_p 1(bias)					
R_p 2(bias)					
R_p 3(bias)					

Table 22.1

2. Dynamic study

(1) Disconnect R_L, input V_i with 1KHz, 3mV_{RMS} sine wave，observe the waveform of V_i,V_0 and compare their phase.

(2) Keep the frequency constant, increase the amplitude gradually, observe V_0 maximum distortionless value, tabulate.

$R_L=\infty$

Measure value		Calculate value	Estimate
V_i(mV)	V_0(V)	A_v	A_v

Table 22.2

(3)Keep V_i＝5mV, connect load R_L, measure the voltages V_0 with varied R_L, tabulate.

Given parameter		Measure value		Calculate value	Estimate
R_d	R_L	V_i(mV)	V_0(V)	A_v	A_v
30k	20k				
30k	30k				
30k	40k				

Table 22.3

(4) Keep V_i=5mV, change R_P, observe the waveform of V_o, measure the voltages V_g, V_s, V_d and tabulate.

R_P	V_g	V_s	V_d	Output wave form
Max.				
Appropriate				
Min.				

Table 22.4

3. Measure amplifier input and output resistance

(1) Measure input resistance

Tandem connect a resistor 5K1 as Figure 22.2, measure V_s and V_i, then calculate r_i.

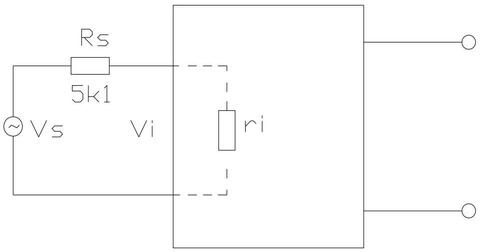

Figure 22.2

(2) Measure output resistance

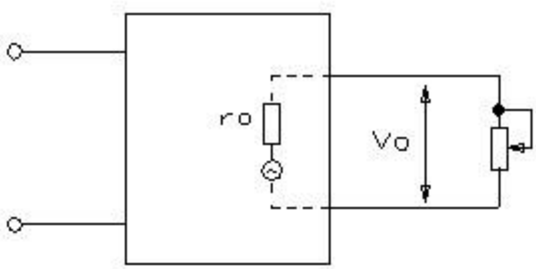

Figure 22.2

Connect an adjustable resistor on the output as a load, set a suitable R_L make amplifier output distortionless (by oscilloscope). Measure V_o with and without load, then calculate r_o, and tabulate.

Measure input resistance				Measure output resistance			
Measure		Calculate	Estimate	Measure		Calculate	Estimate
V_s(mV)	Vi(mV)	r_i	r_i	V_o $R_L=\infty$	V_o R_L	r_o	r_o

Table 22.5

Experimental report

1. Summarizes the characteristics of FET.
2. Compare the characteristics with the corresponding characteristics of transistor.