1. INTERFERENCE COUPLING

This first part consists of basic experiments with an oscilloscope, signal generator and different kinds of cables (ordinary, shielded and twisted pair). Aimed to indicate the presence of electromagnetic fields and create acquaintance within different ways of interference coupling (electric and magnetic field) under different conditions.

1.2. THE PRESENCE OF ELECTRIC AND MAGNETIC FIELDS

First we investigate the electric and magnetic fields around us by using an oscilloscope, a normal lab cable and a coil.

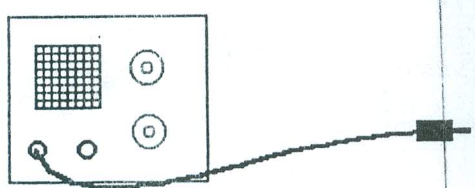


Fig 1.

Discovering electric fields.

1 2.1. ELECTRIC FIELDS

Connect the lab cable to one of the oscilloscope inputs (you need a coax-to-banana converter) and try to find some electrical signals on the screen.

a) What do you find? (Frequency and voltage).

b) Where does this signal come from?

Move the cable around and observe if the signal changes. Put your finger on the metal part of the plug.

c) What happens and why?

1.2.2. MAGNETIC FIELDS

To investigate the magnetic fields we need some kind of cable loop. To achieve a decent deflection on the oscilloscope a good idea is to use a loop with many turns, a coil. Here 100 turns of enamelled copper thread around a bobbin is used as a coil. Connect the coil to one of the inputs and move the coil around to find some signals. Move the coil near the different parts of the oscilloscope until you obtain a maximum voltage.

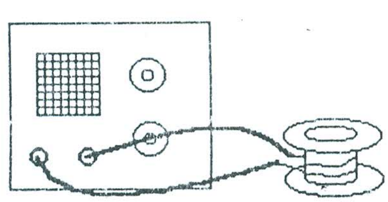


Fig 2

Discovering magnetic fields.

a) What do you find? (Voltage and frequencies). Explain the result and find the origin of this maximum signal.

b) Calculate the maximum magnetic field strength from the maximum measured voltage. First calculate the inductance for the coil.

1.3. CAPACITIVE AND INDUCTIVE COUPLING

To be able to investigate the capacitive and inductive coupling in a more controlled way we use the UNILAB signal generator as a source of interference by feeding a lab cable with signal and use an oscilloscope to measure the induced voltage in a parallel wire, terminated by a 1 kohm resistor.

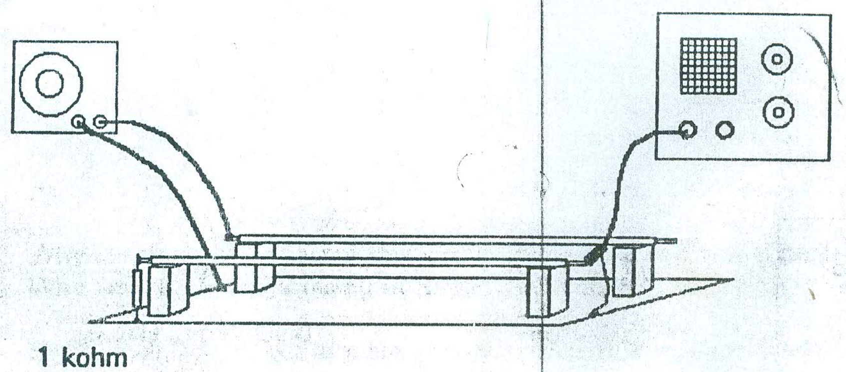


Fig 3

Connections

1.3.1. CAPACITIVE COUPLING

PREPARATION QUESTIONS:

PQ1 Use the theory part and calculate the capacitance between two 80 Cm long conductors with 2 mm diameter and 10 Cm distance. Calculate for two cases, 5 and 10 Cm above the ground plane. Assume air around the conductors, having about the same dielectricity constant as vacuum.

PQ2 Calculate on basis of the above results the expected interference voltage on the receptor cable if the source voltage is 6 V and the frequency 50 kHz.

PQ3 If you want to measure the interference voltage in a controlled way, should you use a probe or a normal lab cable to be connected between the receptor cable and the oscilloscope? Why?

PQ4 If we double the frequency from the interfering source, how much would you expect the interfering voltage to rise?

PQ5 Calculate the expected interfering voltage if you place the receptor cables 5 Cm apart and 5 Cm above the ground level. (50 kHz)

PQ6 In what places would you (according to the theory part) ground the shield in fig 4c?

PQ7 If you use square wave instead of sinusoid, what will happen to the interfering voltage? Why?

PROCEDURE

-Put an ordinary lab cable in one of the plastic tubes and place it on one pair of 10 Cm high wooden blocks on the ground plane.
-Connect one of the cable ends to the 100 ohm output of the signal generator.
-Let the other cable end be free.
-Connect the generator ground output to the ground plane.
-Put the unshielded cable in the other tube and place it on the other pair of 10 Cm high wooden blocks, parallel with the other tube at a distance of 10 Cm (centre - centre).

-Connect the 1kohm resistor to the ground plane and the other end of the cable to the oscillator probe.
-Connect the ground clip from the probe to the ground plane.
-Adjust the signal generator to 50 kHz sinusoid signal and maximum output level (about 6 V).

a) Measure the interfering voltage (peak to peak) received by receptor cable.

b) Increase the frequency to 100 kHz and measure the interfering voltage (peak to peak) received by the receptor cable.

c) Lay the wooden blocks down so that the tubes are 5 cm above the ground plane. Maintain 10 Cm distance between the two cables. Restore the frequency to 50 kHz and measure the interfering voltage (peak to peak).

d) Move the cables 5 Cm apart (centre - centre) and measure the interfering voltage.

e) Switch the signal generator to square wave and measure the interfering voltage (peak to peak).

	10 Cm height 10 Cm apart 50 kHz sine	10 Cm height 10 Cm apart 100 kHz sine	5 Cm height 10 Cm apart 50 kHz sine	5 Cm height 5 Cm apart 50 kHz sine	5 Cm height 5 Cm apart 50 kHz square
Measured voltage (peak to peak)					
Calculated voltage.					

Table 1

f) Connect the cables according to fig 4 a-d and measure the resulting interfering voltages (Use sinusoid signal).

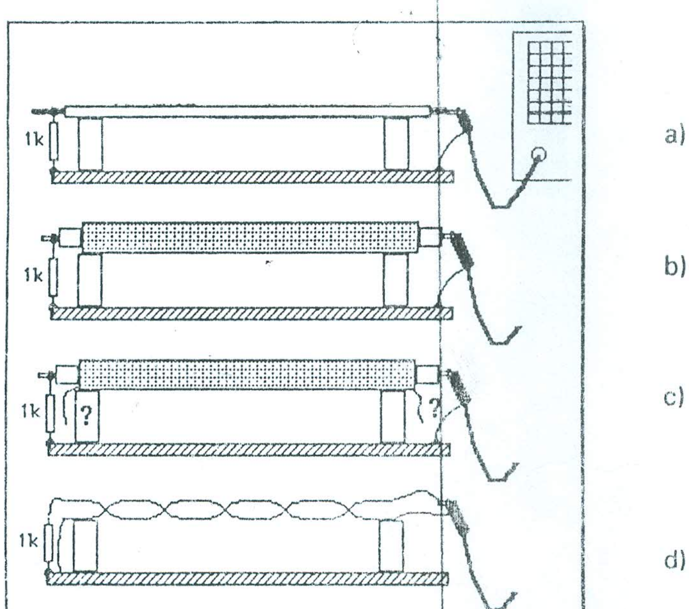


Fig 4.
Receptor cable connections.

Fig 4	Receptor cable and connection	Interfering voltage (peak to peak)	Attenuation (dB)
a	Single cable		0 dB
b	Shielded cable (Ungrounded)	-	
c	Shielded cable (Grounded)		
d	Twisted pair cable		

Table 2

EVALUATION

Compare the values and expectations from the preparatory questions with the obtained results from the experiments and comment on each specific point.

1.4. INDUCTIVE COUPLING.

Use the low impedance output (1Ω) on the UNILAB signal generator and ground the loose end of the interfering cable (transmitter cable) through a series resistance of 6.8Ω (9W). Be sure that you DO NOT SHORT CIRCUIT the loose end of the cable directly to the ground. Then you are sure to damage the signal generator.

In this way we will have a considerable current flowing through the cable, through the resistor and back to the generator through the ground plane.

The receptor cables are to be connected as before.

PREPARATION QUESTIONS

PQ8 Use the theory part and calculate the mutual inductance between two 80 Cm long conductors with 2 mm diameter and 10 Cm distance. Calculate for two cases, 5 and 10 Cm above the ground plane. Assume air around the conductors, having about the same magnetic properties as vacuum.

PQ9 Calculate on basis of the above results the expected interference voltage on the receptor cable if the source current is 0.8 A and the frequency 50 kHz.

PQ10 If we double the frequency from the interfering source, how much would you expect the interfering voltage to rise?

PQ11 Calculate the expected interfering voltage if you place the receptor cables 5 Cm apart and 5 Cm above the ground level. (50 kHz)

PQ12 If you use square wave instead of sinusoid, what will happen to the interfering voltage? Why?

PQ13 In what places would you (according to the theory part) ground the shield in fig 4c?

PROCEDURE

Adjust the output level of the signal generator so that you get 0.8 A, 50 kHz sinusodial signal. (Measure the current by measuring the voltage output, using the oscilloscope).

a) Measure the interfering voltage (peak to peak) received by the receptor cable.
b) Increase the frequency to 100 kHz and measure the interfering voltage (peak to peak) received by the receptor cable.

c) Lay the wooden blocks down so that the tubes are 5 cm above the ground plane. Maintain 10 Cm distance between the two cables. Restore the frequency to 50 kHz and measure the interfering voltage (peak to peak).

d) Move the cables 5 Cm apart (centre - centre) and measure the interfering voltage.

e) Switch the signal generator to square wave and measure the interfering voltage (peak to peak).

	10 Cm height 10 Cm apart 50 kHz sine	10 Cm height 10 Cm apart 100 kHz sine	5 Cm height 10 Cm apart 50 kHz sine	5 Cm height 5 Cm apart 50 kHz sine	5 Cm height 5 Cm apart 50 kHz square
Measured voltage (peak to peak)					
Calculated voltage.					

Table 3

f) Connect the cables according to fig. 4 a-d and measure the resulting interfering voltages (Use sinusoid signal).

Fig 4	Receptor cable and connection	Interfering voltage (peak to peak)	Attenuation (dB)
a	Single cable		0 dB
b	Shielded cable (Ungrounded)		
c	Shielded cable (Grounded)		
d	Twisted pair cable		

Table 4

EVALUATION.

Compare the values and expectations from the preparatory questions with the obtained results from the experiments and give comments on each specific point.

1.5. CONCLUSIONS

a) How would you reduce capacitive coupling.
b) How would you reduce inductive coupling.

Give full answers, including both results from your experiment and information given in the theory part.

2. RADIO FREQUENCY INTERFERENCE

Throughout this part, an AM/FM-radio receiver is used as a receptor for electromagnetic radiation fields.

2.1. FARADAY CAGE

A simple shield (of Faraday-cage type), can be made of chicken-net. It must totally enclose the inner volume, and it must be quite close-meshed.

Adjust the wireless so that a station (e.g. Radio Mulungushi) can clearly be heard. Put the radio in the chicken-cage so that the cage completely encloses it (keep the antenna short and inside the cage).

What happens and why?

3 COMPUTER INTERFERENCE

In close proximity to e.g. a computer, the radio will be interfered, due to the quick transitions in the square pulses (high frequencies) and also because of other electronic devices like the CRT and disk-units etc. in the computer. Put the radio close to a computer and adjust the frequency until you can hear the varying bit flow, preferably when a program is running.

Comments.

Lab 4 OSCILLOSCOPES

OBJECTIVE

Practical training in the use of oscilloscope.
Use of delayed sweep
Use of storage oscilloscope
Use of sweep generator and oscilloscope to get frequency response.

REPORT

The students are [illegible] supposed to deliver a report. ⇒ Report to be submitted by students.
not

EQUIPMENT

Feedback 459 + kit 461
Double beam oscilloscope with delayed sweep
Analogue storage oscilloscope
Sweep signal generator
2 Unilab signal generators
* – PM5705 pulse generator

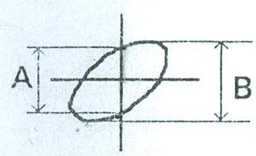
PROCEDURE

1. Connect the output of a Unilab signal generator to one of the channel inputs and set it on sine wave, full amplitude.
   One of the students choose a frequency without telling the other two, who should use the oscilloscope to find the frequency of the signal.
   Continue with this until all the students in the group have tried to measure the frequency.

2. Set the input switch to AC. Set the Unilab signal generator to square wave, 25 Hz and connect it to the oscilloscope. Trig the oscilloscope to make a steady picture on the screen. Switch the input switch to DC and explain the difference.

3. Use the Feedback 459 + kit 461, and make a highpass filter with a 1µF capacitor and a 1k resistor.
Use the high level output from the Unilab oscillator, sine wave, 100 Hz. Couple this output to the input of the filter and to channel A (or Ch 1) of the oscilloscope. Couple the output of the filter to channel B (or Ch 2).
Select both A and B, so that you have both signals on the screen at the same time and adjust the gain on each channel so that the signals have almost the same amplitude on the screen.
a) Measure the phase difference between input and output of the filter, directly on the screen.
b) Now you keep the connections, but change the settings, so that you have a X-Y display, with the input to the filter as Y and the output as X.

Now you should see an ellipse, and the phase difference between the two signals is given by $\sin\phi = \frac{A}{B}$

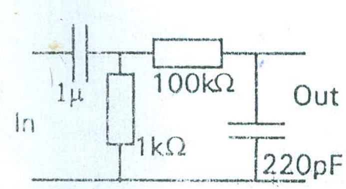


Repeat the phase measurement, both directly and by using the ellipse for 200Hz and 400Hz.

4. Use 2 Unilab signal generators. Turn them both on sine wave and adjust them to about the same frequency. Couple one output to the Y deflection and the other to the X deflection. (Use the X-Y position of the time base switch). Adjust the gain for each input so that you have about the same maximum deflection in Y-direction as in X-direction. Study the Lissajou-figure and adjust the frequency from one of the generators until you have a circle or ellipse standing still.
How is now the relationship between the two frequencies?
Adjust the frequency of one of the generators until you have a figure similar to the number 8.
How is now the relationship between the two frequencies?
Experiment more with these Lissajou-figures.

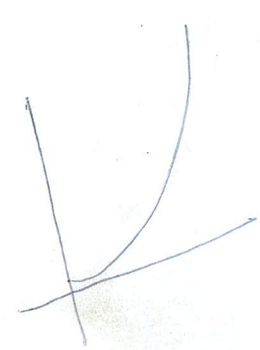
5.

Build a bandpass filter as in the figure. Use a sweep generator to feed the filter.
Let it sweep between 10 Hz and 20 kHz.

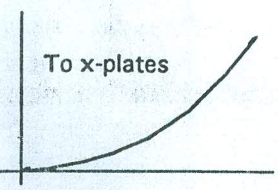


Couple the output of the filter to channel A on an oscilloscope and the deflection output from the sweep generator to the X-input of the oscilloscope. Now you should get the frequency response of the filter directly on the screen.

K22



The sweep generator changes the frequency of its output with time, and at the same time it outputs a signal as in the figure to the right to the X-deflection of the oscilloscope.



STORAGE OSCILLOSCOPE AND DELAYED SWEEP

6 Use a PM5705 pulse generator and set it on 100µs pulse duration and 10 ms repetition rate.
Run the storage oscilloscope as an ordinary oscilloscope and get a steady picture of 2 pulses on the screen. Move the indicator for the delayed sweep until it is underneath the second pulse and change its width until it is broader than the pulse. Turn on the delayed sweep and study the pulse. You may move it with the delay time knob.
Now you trig on the first pulse and start the sweep delayed, so that you get the second pulse displayed on the screen.

7 Turn the oscilloscope back to normal display and increase the sweep speed so that the pulse covers about half the screen. Turn the generator to single pulse (ext) and push the single shot button to see whether you are able to see the pulse on the screen.
Turn the oscilloscope on write and then push erase.
Now you push the single shot button once more. If you do not get a lasting picture on the screen, erase it, increase the sensitivity and try once more.

LAB 5 FAULT FINDING

NB! You have 2 afternoons to complete this lab.

OBJECTIVE

Get training in finding faults in electronic circuits. Learning fault finding techniques.

The theory in this handout is a part of the EE393 course, and will be included in lectures, Assignments, Term tests and exams.

EQUIPMENT

- Fault finding trainer FSC
- Oscilloscope
- Oscilloscope probes
- Digital voltmeter Fluke 45
- Ampèremeter 0-1.5A
- Variable load resistor, 0-63 ohm, 50 W

THEORY

FAULT FINDING TECHNIQUES

An experienced technician will use several of his human senses when looking for a fault, not only electric measurements.

A FAULT FINDING SEQUENCE.

1. What is wrong?

   Define the fault, what is actually wrong?

   Is the fault due to lack of knowledge on how the equipment works? Is there really a fault?

   Very often you get a piece of equipment, e.g. a radio, and is told, "my radio is not good, fix it".

   Be sure to get an accurate description on the fault and how it developed. This will often give a clue to the fault.

   It is important that you know how the equipment is supposed to work, in order to establish the nature of the fault. Read the manual.

2. Is the plug in the socket?

   The fault is severe, perhaps the equipment is all dead. The first you should check is whether the equipment gets power. Is the plug in the socket? Is the fuse blown? Is the On-button pushed? Repair technicians often get equipment for repair where they only have to put the plug in the socket and switch it on to have it "repaired".

3. Look, smell and feel.

   If the fault persists, open the box. (If you are unsure of how this should be done, get hold of a maintenance handbook. You could quite easily damage the equipment mechanically.)

   Use your eyesight.

   Do you see any loose ends, burned or mechanically damaged components?

   Do you detect any strange or "warm" smells? Are any components much warmer than they ought to be? Touch the suspected components. (Be careful with dangerous voltages.)

   Such preliminary investigations will often lead you directly to the fault, but remember, a burnt component is perhaps not more than the symptom of a fault, not the true fault itself, so do some thinking and measurements before you replace expensive components that are damaged. Perhaps they will be blown at once when you turn on the equipment.

4. *The halving method.*

   The next step is to roughly locate the fault to a certain part of the equipment.

   If your equipment consists of a chain of amplifiers or other blocks where no 2 depends on no 1 and so on, try to locate the fault to a certain part of the chain. If the fault is in the last part and you start looking for the fault from the start, moving through the whole equipment, you will certainly find the fault, but this will be very time consuming.

   You could insert a signal at the input and measure half way through the circuit to see whether you have a correct signal there. If you have, then the fault is probably in the second half, and you could measure again, 1/4 from the end, each time using the principle of halving. In general this is the fastest method when looking for faults and is called the method of halving To use this method you must have some knowledge on the expected shape and magnitude of the signal along the signal path.

5. DC measurements.

   Let us say that you are looking for faults in analogue equipment and are finished with the AC measurements. You have located the fault roughly to a certain part of the equipment, Now is the time for DC measurements.

   Remember that before you measure the DC voltages you should <u>turn off any analogue signals</u>, as they could give wrong DC values due to rectifying effects, saturation etc..

6. Resistance measurements
In the end you may have to measure resistance, to establish the exact faults when the AC and DC measurements have led you to certain conclusions, but here we have several tumbling stones.
Be sure to switch off the power before you start measuring.
Be aware of electrolytic capacitors that are not fully discharged when you measure resistance, as this may give peculiar results. To avoid this you may short circuit the electrolytic capacitors before you measure resistance. NB! do this without power.
Often it is possible to do a lot of "on board" resistance measurements without soldering out the components, but to do this, have a look at the circuit diagram to see the possible routes for the current, so that you roughly know what you should get.
Most errors on diodes and transistors can be found by resistance measurements if the AC and DC measurements indicate an error.

7. Calibration
When you have finished the fault finding and changed components it will often be necessary to calibrate the equipment. As the specifications for the components admit a certain variation of values, voltages and currents may have changed and need adjustment.

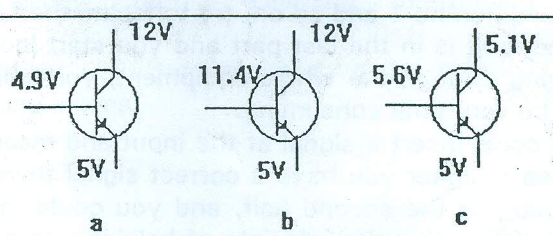
8. Maintenance and repair log
Each piece of equipment should have a maintenance and repair log, keeping track of everything that is done, including calibration, maintenance, faults and repairs.
Whenever a fault develops or you have problem with calibration, you may see what has been done before, and quite often the same fault will develop again.
As the repair technician will change and/ or much time will pass, you should not depend on the memory of the technician alone.

PREPARATION QUESTIONS.

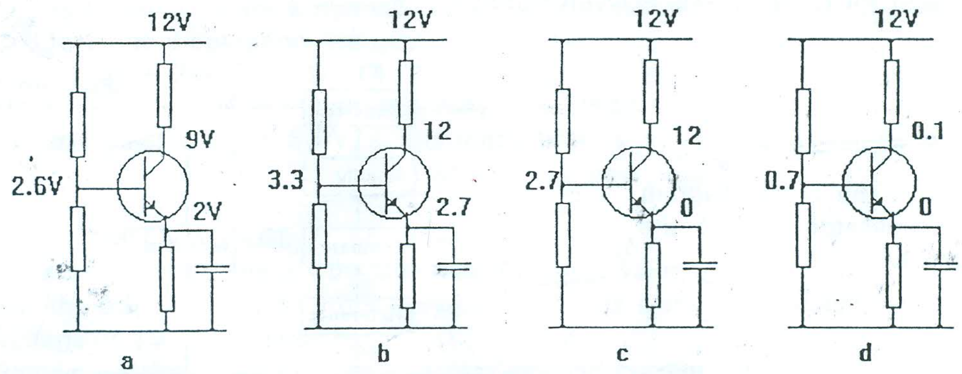
PQ1 *How would you use an ohm-meter to tell whether a diode is ok?*

PQ2 How do you use an ohm-meter to tell IF a small signal PNP transistor is faulty ?

PQ3 One or more of these transistors must be faulty. Which? Why?



P14



Case a is without faults. In b, c and d, there are one or more possible faults giving the voltages shown. Which possible faults would you suggest for b, c and d?

P15 You suspect a capacitor to be faulty. How would you establish this fact?

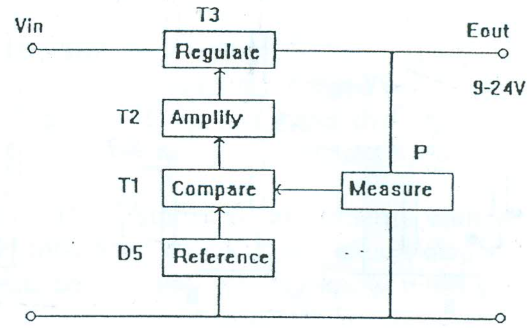
DESCRIPTION OF THE POWER SUPPLY

The fault finding trainer FSC is a fully operative standard power supply, a series regulator.
It is equipped with a row of switches used to set faults, one at a time.
First we measure on the faultless power supply to know the normal operating voltages, and then we introduce faults, one at a time and try to find the faulty component. To do this we use a multimeter and an oscilloscope. All the necessary measuring points can be reached from outside. There is no need to open the case.

The power supply has a stabilised output and is fed from 220V, 50Hz AC mains.
The output voltage E may be adjusted from 9 to 24 V by adjusting the potentiometer P.
The output voltage E is stabilised against variations in input voltage and output load.
The maximum output current should be 1 A DC. In case of overload, the power supply is shut down and will remain down until the overload is removed and push button SW_2 is pressed.

FUNCTIONAL DESCRIPTION OF THE POWER SUPPLY.

Fig 1 shows the block diagram for the stabilisator part of the power supply.



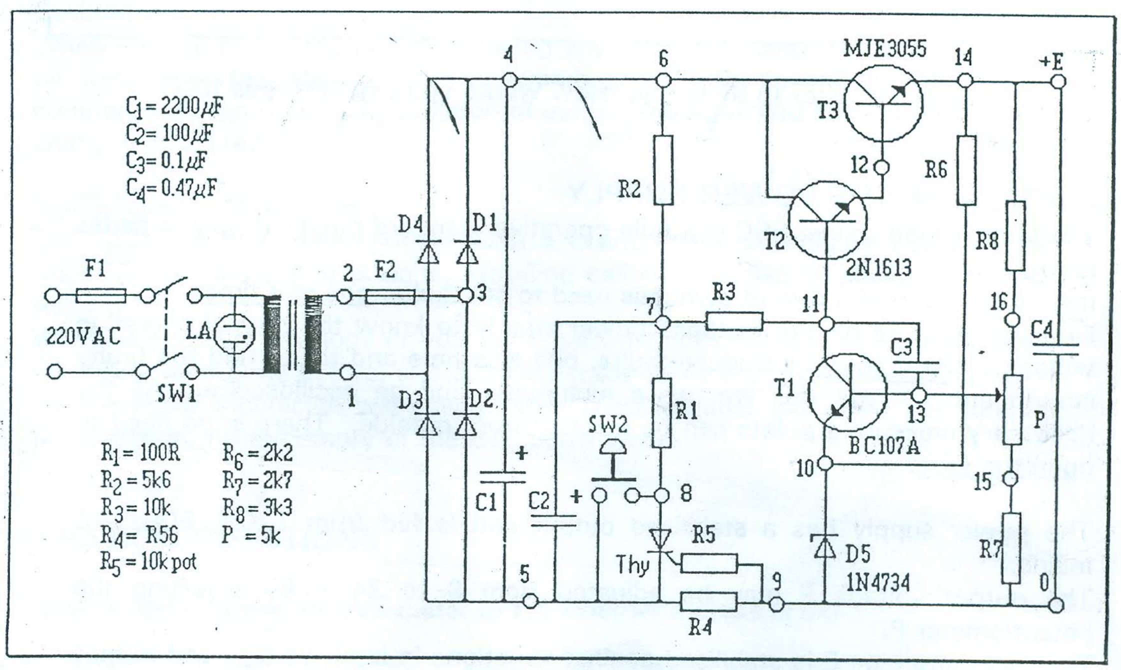


Fig 3

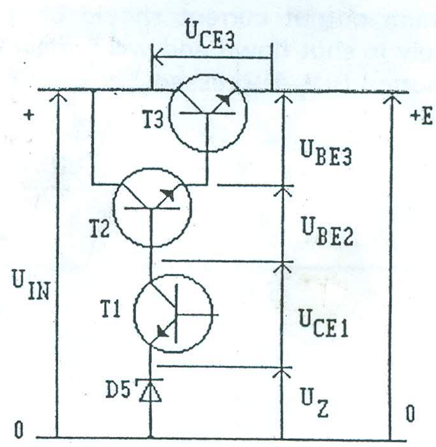
Simplified diagram showing the voltages in the regulator and how they add.

We may write

$E = U_Z + U_{CE1} + U_{BE2} + U_{BE3}$ (1)

or

$E = U_{IN} - U_{CE3}$ (2)



LOWEST OUTPUT VOLTAGE.

From equation (1) we get the lowest value fo E that the regulator can give.

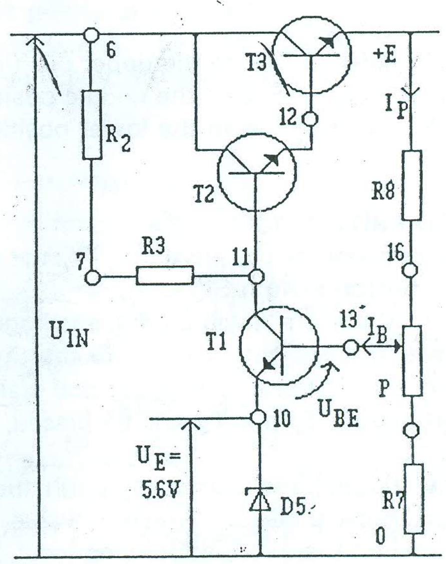
U_{BE} is about 0.7V for a normally biased silicon transistor, and as U_{CE} must be >0 for normal operation, we get:
$E_{min} = U_Z + 2*0.7 = U_Z + 1.4V$.
Here $U_{CE1} = 0V$ (The transistor is fully saturated.)
In our regulator, $U_Z = 5.6V$, so the theoretical minimum output voltage is 7V

HIGHEST OUTPUT VOLTAGE

From equation (2) we get the theoretical highest value of E.
For the transistor T_3 to work normally, it needs a minimum collector/ emitter voltage of 1V. This gives $E_{max} = U_{IN} - 1$ volt.
Remember that U_{IN} drops with increasing load current, so the value used for U_{IN} should be the input voltage at full load.
In this practical design we have not used the theoretical limits E_{min} and E_{max}.
By the use of R_7 and R_8 we have got 9V and 24V.

THE START AND THE REGULATION.

When SW1 is operated, T_2 and T_3 get their collector voltage from the rectifier. C_2 is charged through R_2, and T_2 gets its base current from R_3, which also is the collector resistor of T_1. (We suppose that the thyristor TY is not conducting.)
The emitter current of T_2 is the base current of T_3. Then T_3 is delivering current to the zener diode D_5 through R_6, thereby giving 5.6V across D_5 with [+] at the emitter of T_1. The transistor T_1 is now "comparing" the voltages at the emitter and the base.



TOO HIGH OUTPUT VOLTAGE.

The voltage at test point 13 is directly related to the output voltage, and if it increases, the base current of T_1 will increase, giving an increase in the emitter current.
When the emitter current increases, the voltage at test point 11 decreases, which in turn will give a drop in the voltage at E, the output.
The voltage drop at E follows from the fact that there is a constant voltage drop of 1.4 volt from the base of T_2 to the emitter of T_3
As the output voltage is reduced, the voltage at test point 13 is also reduced until the voltage there is $U_Z + 0.7$ volts, in our case 6.3V. Then we have balance.

TOO LOW OUTPUT VOLTAGE.

This will make the base voltage of T_1 (test point 13) drop, and if it drops below 6.3V, the base current will decrease, giving a decrease in the emitter current, which in turn will make the voltage at test point 11 higher. Then the output voltage will increase as will, until the voltage at test point 13 is equal to U_z + 0.7 volts. Thus we see that the voltage at test point 13 is always held at 5.6 + 0.7 = 6.3V due to the effect of the negative feedback.

CHOICE OF OUTPUT VOLTAGE

The voltage at test point 13 may be expressed as the output from a potential divider (assume $I_{R1} << I_P$, see fig 4):	$U_R = E \frac{R_7 + \text{lower part of P}}{R_8 + P + R_7}$
As U_R (voltage at test point 13) is held at a constant 6.3V, we find E from this equation:	$E = U_R \frac{R_8 + P + R_7}{R_7 + \text{lower part of P}}$
From this we see that the output voltage varies with the setting of P.	$E_{min} = U_R \frac{R_8 + P + R_7}{R_7 + P}$ $E_{max} = U_R \frac{R_8 + P + R_7}{R_7}$

PQ6 Calculate E when
a) the slider of P is at the upper position.
b) The slider of P is in the middle position.
c) The slider of P is in the lower position.

OVERLOAD PROTECTION

This consists of the thyristor TY, the resistors R_1, R_4 and R_5 in addition to the push button switch SW_2.
The load current I_L will create a voltage drop U_4 across the "sampling" resistor R_4 which gives gate voltage to the thyristor. When this voltage reaches about 0.6V, the thyristor is trigged, and clamps the base voltage of T_2 to nearly 0V. Then neither T_2 nor T_3 will be biased, and will be cut off, thereby giving 0 volt output.
Once trigged, the current through the thyristor will continue until the current drops below a certain threshold value. Then the output voltage will stay at 0V even when the overload is removed.
To make the circuit working again, we must reduce the current through the thyristor below the threshold current by short circuiting it with the push button switch SW_2. When we release SW_2, the circuit will working as normal if the overload at the output is removed.

PQ7 Calculate theoretically the maximum permitted load current:

MEASUREMENTS ON THE POWER SUPPLY

1. Be sure to turn off all the faults (the switches on the back should all be down).
2. Adjust "SET E" midway. Start the circuit with SW_1, without load.
3. Turn "SET E" to the right as far as it goes. Measure E_{max} :_
4. Turn "SET E" to the left as far as it goes. Measure E_{min} :
5. Adjust "SET E" until you get 20V output and fill in the table, using fig 5.

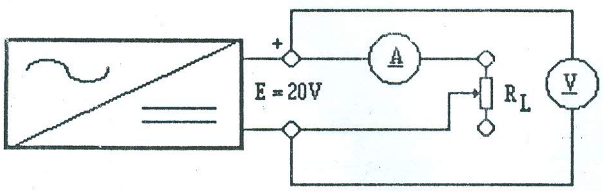


Fig 5

IL (A)	E (V)		IL (A)	E (V)
0			0.4	
0.6			0.8	

6. At which current is the overload protection activated? What is the output voltage when it is activated?

7. Measure the "no fault" voltages at the different test points and note them in the circuit drawings below when the load is 0 A and 0.7 A. Let the output voltage be 20V. Use these "normal" values when you later are going to find faults.

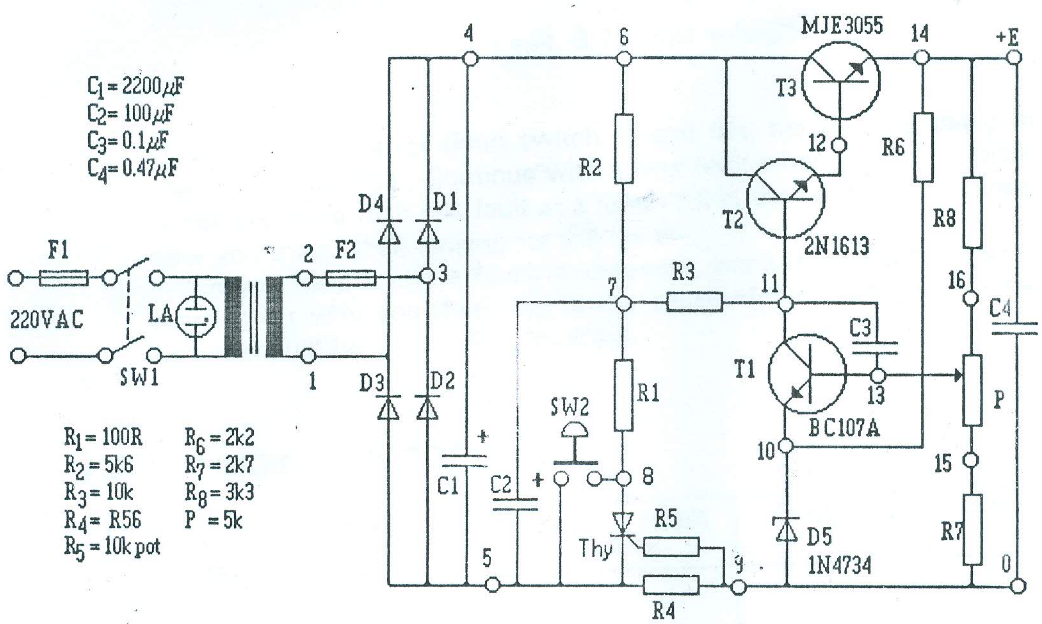


Fig 6. No Fault, No load -voltages

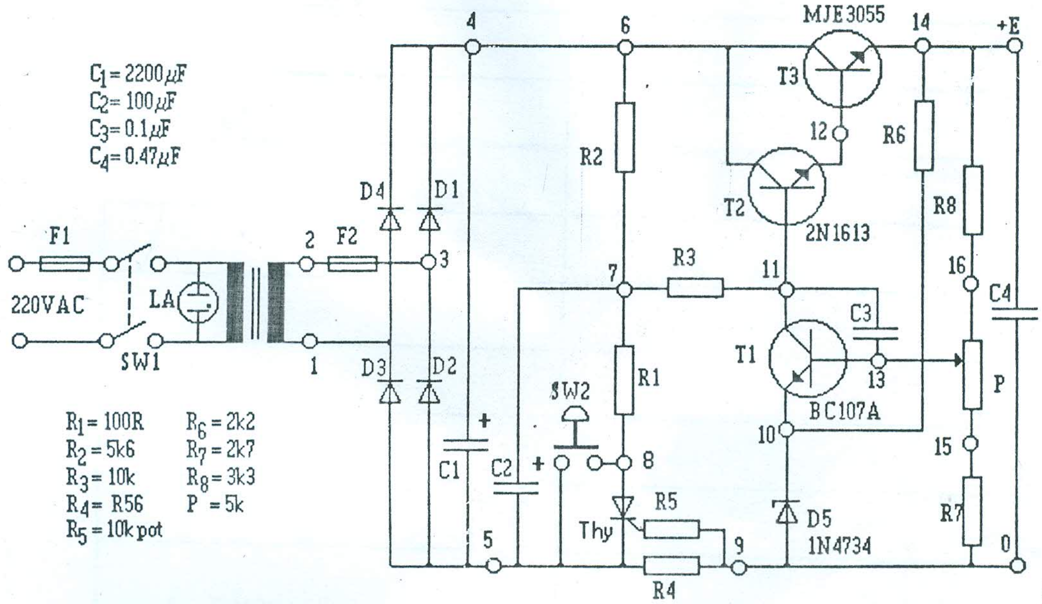


Fig 7. No Fault, 0.7A load voltages

8. Turn on the first error (fault switch 1) and find the fault by using multimeter, and/ or oscilloscope. Continue with a new fault when you have sorted this out. Never use more than one fault at a time. Fill in the fault finding forms, to show how you think when looking for the faults.
When you have found a faulty component, mark it on the form and give your reasons for why you think this is the cause of the fault. Remember that the circuit should function with a load too.

FAULT FINDING PROTOCOL.

Fault number	Symptom or measurement result	Conclusion from measurement
