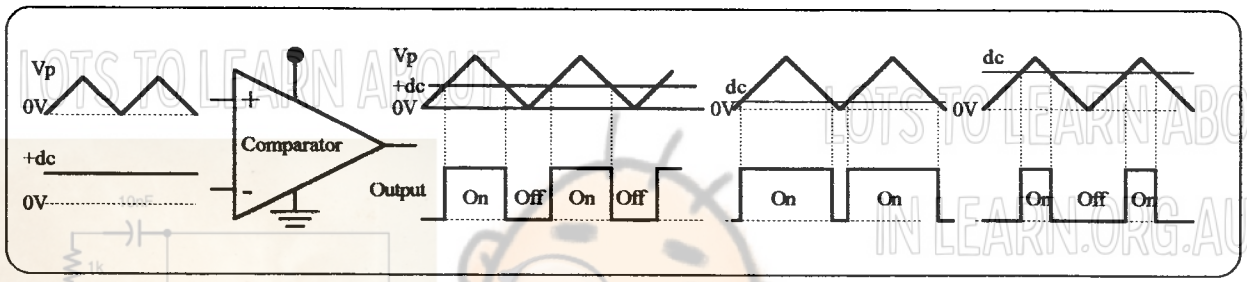
LESSON 7 - SWITCHED MODE POWER SUPPLIES 2

PULSE MODULATOR PRINCIPLES

The purpose of the pulse modulator is to provide the chopper transistor of a switched mode power supply with a drive waveform that causes the chopper to conduct for longer or shorter periods depending on the load current requirements. One method of achieving the on/off time ratio is to use a triangular wave generator and compare it with a sampled dc fron the output of the regulator.

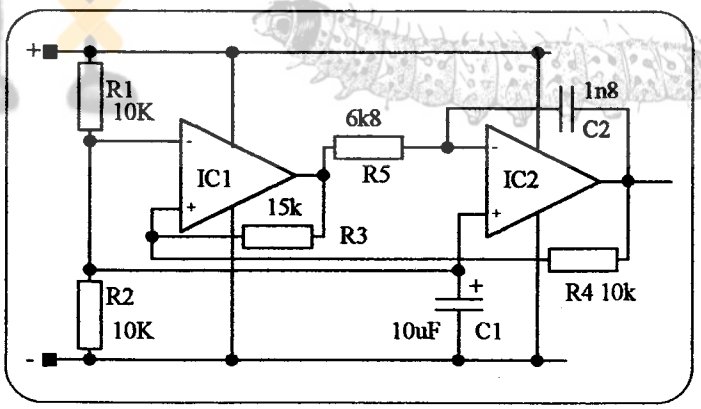
COMPARATOR OPERATION



- The waveform at the positive terminal of the comparator can be sawtooth or triangular in shape.
- The dc level is from the output of an error amplifier.
- At the trip points of the comparator, the output will switch within a volt of vcc and ground.
- The waveform generator is maintained at a fixed frequency and only the mark/space ratio of the comparator changes and hence controlling the chopper transistor.

TRIANGULAR WAVE GENERATOR

- The (+) terminal of IC1 and the (-) terminal of IC2 is set at approx. Vcc/2. (trip point) by R1 and R2.
- Positive feedback from the output of IC1 to its (+) terminal causes a square wave at the output of IC1 that swings to within a volt of Vcc and ground..
- The output of IC1 drives IC2 which will integrate the square wave into a triangular wave which can now be applied to the comparator circuit.



- The frequency of operation can be found from

$$f = [1/(4 \times R5 \times C2)] \times (R3/R4) \text{ Hz}$$

- The exact circuit may vary from the one above.

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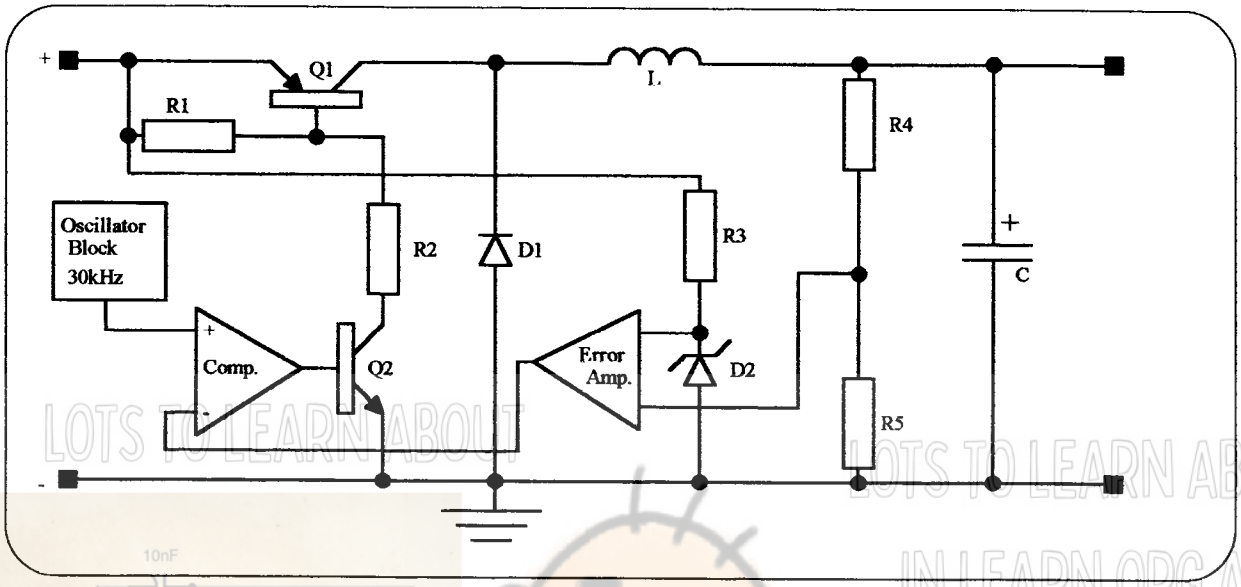
SAMPLE CONSTANT FREQUENCY SWITCHED MODE REGULATOR



- The oscillator block produces the triangular waveform at a constant frequency.
- R4 and R5 sample to output voltage and the error amplifier produces a dc output voltage dependent on the comparison with the reference source D2.
- The square wave produced by the comparator drives the NPN transistor Q2 which in turn drives the chopper transistor Q1.
- Transistor Q1 is a PNP type which can help improve the overall efficiency of the circuit by minimising the voltage drop from emitter to collector under saturation conditions.
- The power supply for the error amplifier and the comparator may by pre-regulated by a zener diode to improve overall circuit performance since the outputs do not have to swing the full input voltage to make the circuit work correctly.

CONSTANT FREQUENCY I.C. SWITCH MODE REGULATOR

The SILICON GENERAL SG3524 or the NATIONAL SEMICONDUCTOR LM3524 is an example of a constant frequency variable mark/space ratio switched mode regulator with all the required basic blocks.

- The addition of resistors, capacitors and perhaps external chopper transistors allow the construction of step-up, step-down and inverting mode configurations.
- The internal configuration allows for single ended or push-pull drive (next lesson).
- Current overload is provided by using a small resistor in the ground return lead. The sense voltage is approximately 200mV.
- The maximum input voltage is listed as 40V but other versions allow for a 60V maximum input.
- Remote safe shut down of the chip is provided.

The hand out on the LM3524 list more features and sample circuits that should be studied in relation to the foregoing notes. Other manufacturers have similar IC switched mode regulators available but with slightly differing features.

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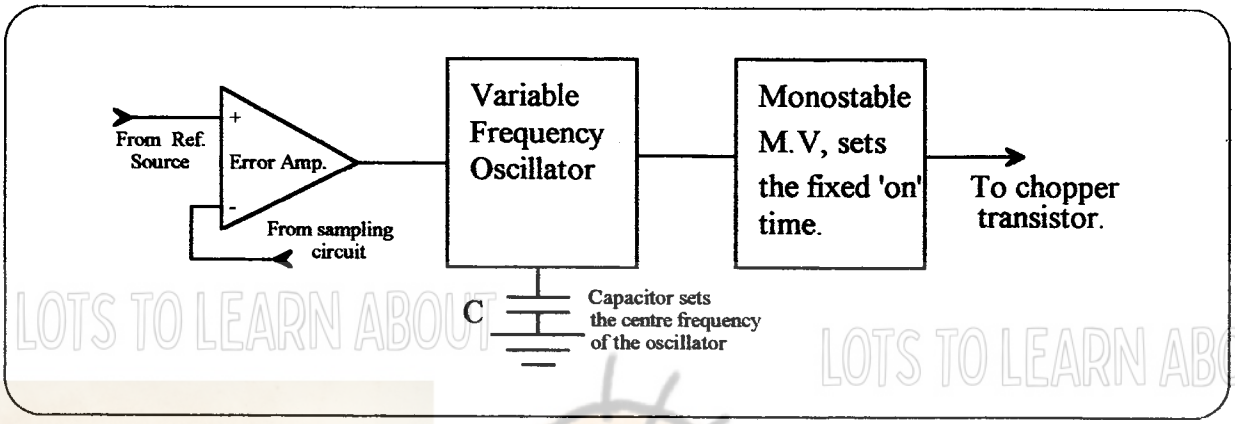
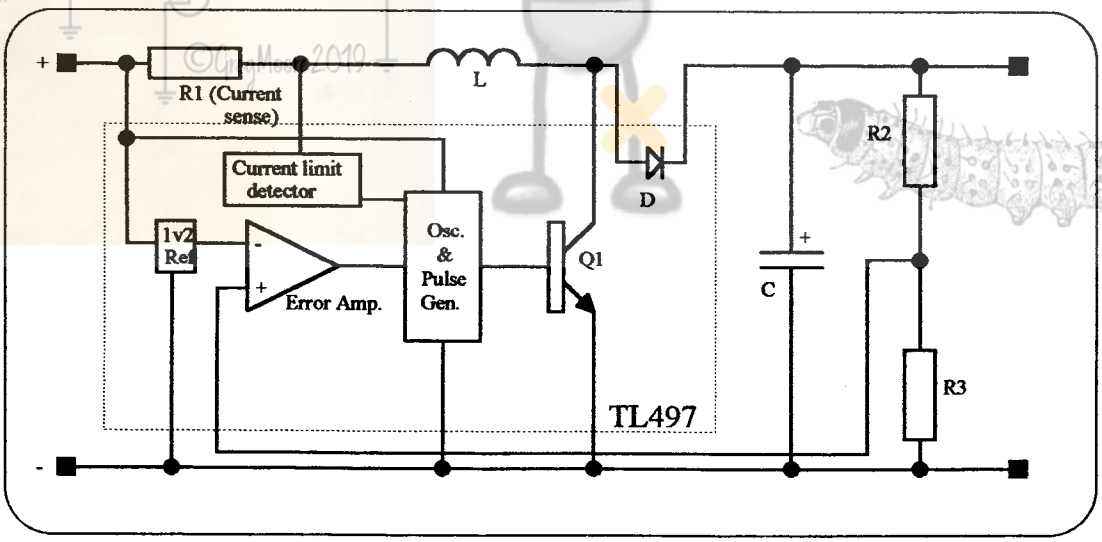
CONSTANT ON TIME, VARIABLE FREQUENCY SWITCHED MODE REGULATORS

Another method of producing a variable mark space ratio is to fix the on time of the chopper transistor and vary the frequency of the drive oscillator with the error amplifier.



- The variable frequency oscillator may be an ASTABLE MULTIVIBRATOR which is easily controlled by a dc input voltage but there are a number of circuits that can perform the role.
- The MONO-STABLE MULTIVIBRATOR requires an input pulse to activate it and gives a fixed time output pulse.
- Methods other than the one shown are used.

FIXED 'ON' TIME IC REGULATOR



The TL497 from TEXAS INSTRUMENTS is an example of a variable frequency/fixed on time switched mode regulator. It has been designed to minimise the number of external components needed to construct a switched mode regulator. The manufacturers short form lists the other configurations possible.

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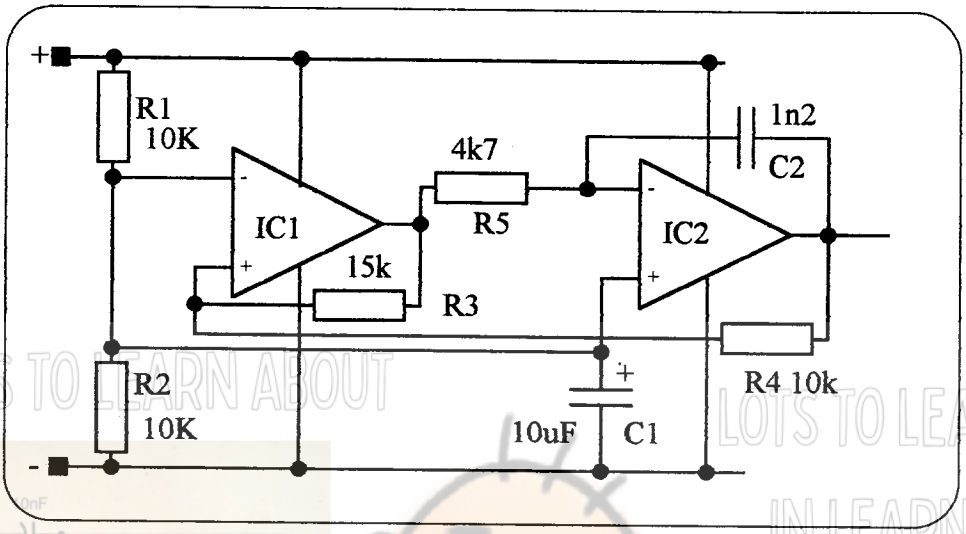
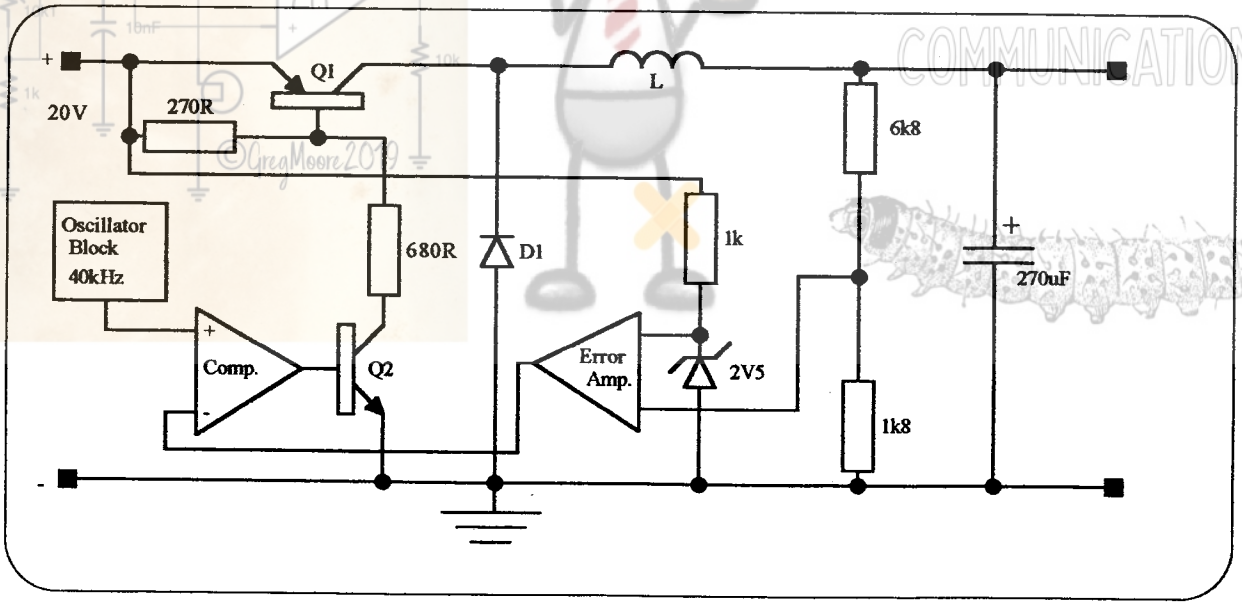
PRACTICE PROBLEMS

Q.1 Refer to the following circuit.



i) Briefly describe the waveform that is found at the output of IC1.
ii) State the circuit configuration formed by IC2.
ii) Calculate the approximate frequency of operation.

Q2 Refer to the following circuit. The mark/space ratio is 1.5:1 if loaded with an RL of 120R.



i) Calculate the on/off times of the regulator.
ii) Calculate the output voltage
iii) Briefly describe the operation of the comparator in this circuit.
iv) State the voltage at the output terminals if Q2 were to become open circuit.
v) Would the 'on' time of the regulator increase or decrease if RL dropped to 100R ?

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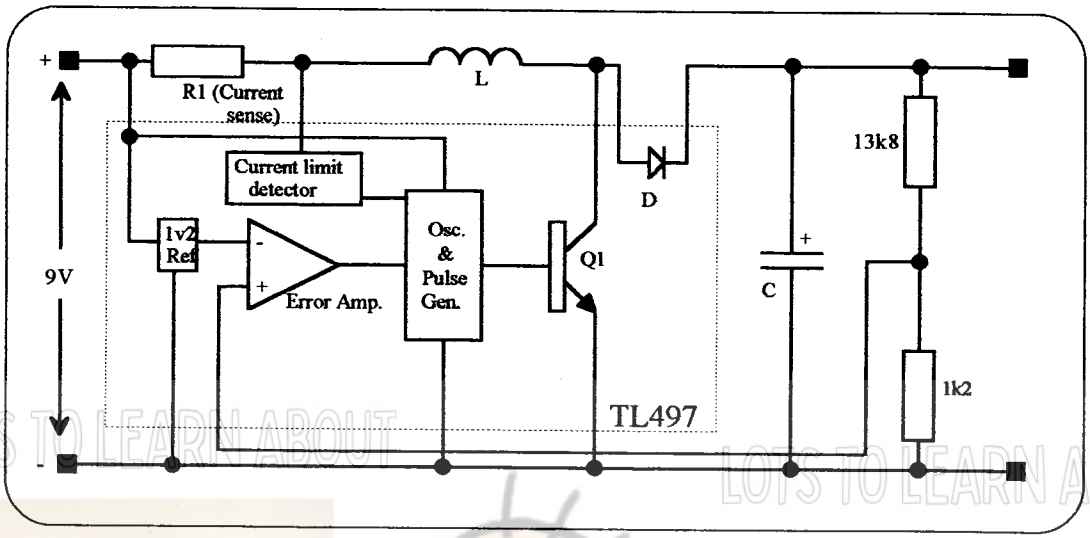
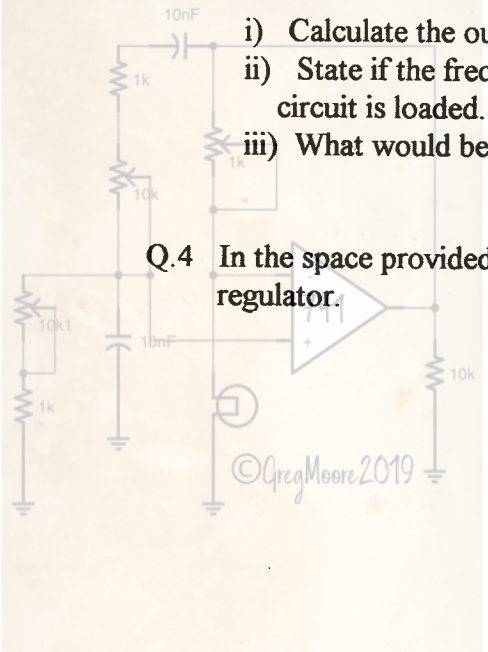
Q.3 Refer to the following circuit. The oscillator operates at 13.34kHz and the "on' time is fixed at 30µsec.



i) Calculate the output voltage for this circuit in the shown unloaded condition.
ii) State if the frequency of the oscillator will increase or decrease when the circuit is loaded.
iii) What would be the output voltage symptoms if Q1 became open circuit.

Q.4 In the space provided below, sketch a circuit of the TL497 used as a step down regulator.



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These questions will help you revise what you have learnt in Section 6.

Tick the correct box.

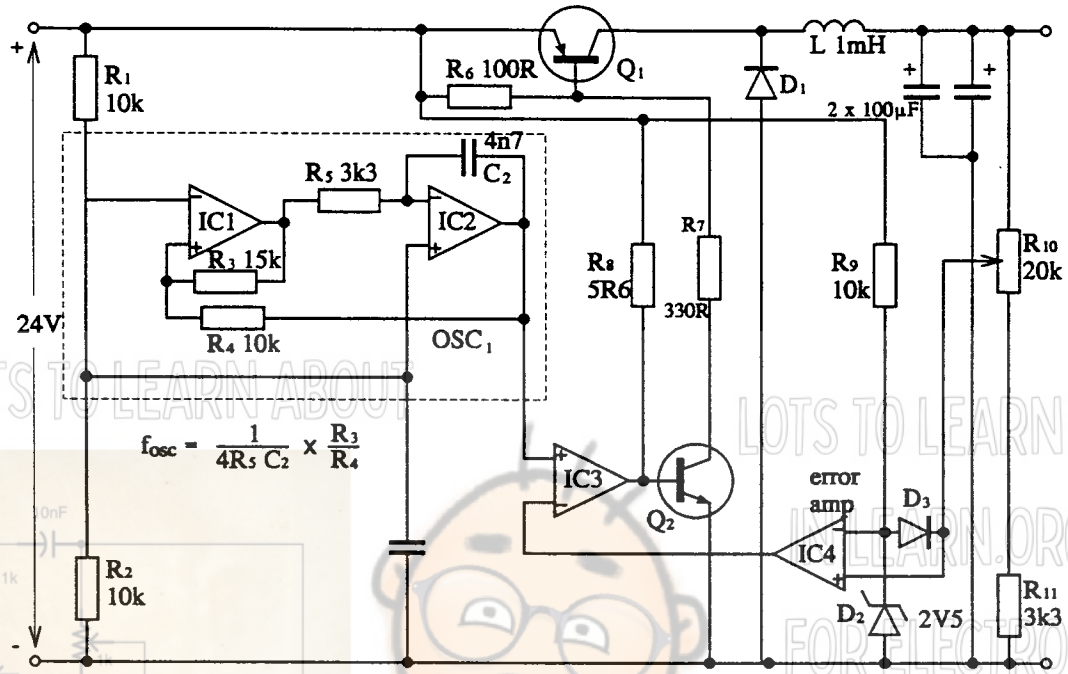


Fig. 1

1. Refer to the circuit in Fig. 1. The output waveform of the oscillator block is a:

   ☐ sine wave
   ☐ square wave
   ☐ triangular wave
   ☐ pulsed wave.

2. Refer to the circuit in Fig. 1. The output waveform of IC3 has a:

   ☐ constant pulse width
   ☐ constant frequency
   ☐ variable amplitude
   ☐ variable period.

3. Refer the circuit in Fig. 1. The output of IC4 is a:

   ☐ varying frequency
   ☐ fixed frequency
   ☐ constant pulse width
   ☐ DC voltage level.

4. Refer to the circuit in Fig. 1. The waveform at the collector of transistor Q1 has a pk-pk amplitude approximately equal to:

   - ☐ the input voltage
   - ☐ the output voltage
   - ☐ half the output voltage
   - ☐ the reference voltage.

5. Refer to the circuit in Fig. 1. If transistor Q2 become open circuit between collector and emitter, the output voltage would:

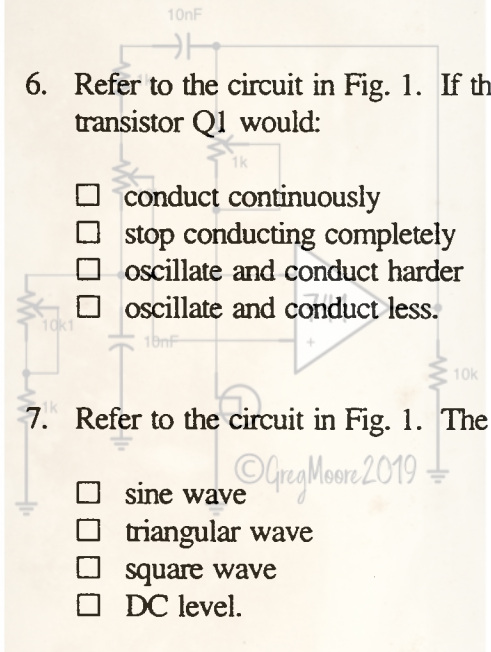
   - ☐ become equal to the reference voltage level
   - ☐ rise to near the input voltage level
   - ☐ fall to near zero voltage level
   - ☐ remain at these voltage level.

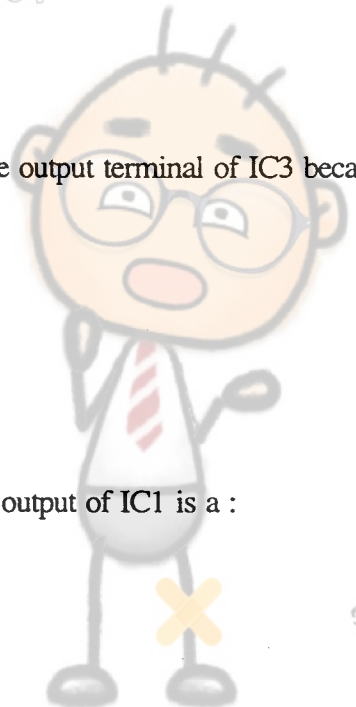
6. Refer to the circuit in Fig. 1. If the output terminal of IC3 became an open circuit, transistor Q1 would:

   - ☐ conduct continuously
   - ☐ stop conducting completely
   - ☐ oscillate and conduct harder
   - ☐ oscillate and conduct less.

7. Refer to the circuit in Fig. 1. The output of IC1 is a :

   - ☐ sine wave
   - ☐ triangular wave
   - ☐ square wave
   - ☐ DC level.





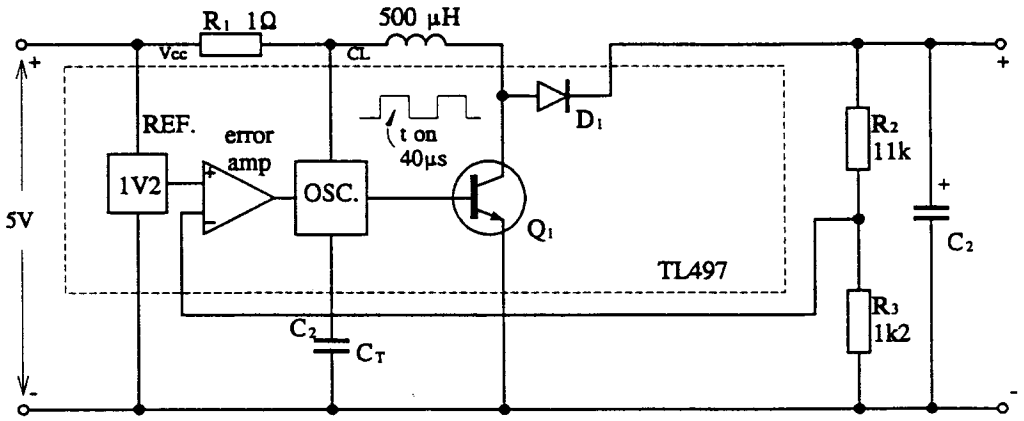


Fig. 2

8. Refer to the circuit in Fig. 2. The TL497 has an oscillator with a constant 'on' time. This means that the oscillator frequency:

   - ☐ rises with increasing output voltage
   - ☐ falls with increasing output voltage
   - ☐ stays constant with varying output voltages
   - ☐ maintains a constant 'off' time with varying output voltages.

9. Refer to the circuit in Fig. 2. This circuit charges the capacitor C2:

   - ☐ when transistor Q1 is conducting
   - ☐ when diode D1 is cut off
   - ☐ during the 'off' time of the oscillator
   - ☐ during the 'on' time of the oscillator.

10. For the circuit in Fig. 2, the input current is:

    - ☐ smaller than the output current
    - ☐ equal to the output current
    - ☐ greater than the output current
    - ☐ constant with varying output current.

11. Refer to the circuit in Fig. 1. Using the equation for the oscillator frequency shown on the circuit diagram calculate the:

    - operating frequency _____
    - duration of the positive half cycle _____
    - duration of the negative half cycle _____

12. Refer to the circuit in Fig. 1 and calculate the approximate range of output voltage of this regulator.

    _____

13. Refer to the circuit in Fig. 1. List the main function performed by each of the following devices.

    - IC1 _____
    - IC2 _____
    - IC3 _____
    - IC4 _____
    - Q1 _____
    - Q2 _____

14. Refer to the circuit in Fig. 2 and calculate the approximate output voltage of this circuit.

    _____

15. Refer to the circuit in Fig. 2. Use the appropriate equation to calculate the approximate 'off' time of this circuit. (Hint: The 'on' time is given in the circuit diagram.)

    _____