GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES, VOL.7, NO. 4, SEPTEMBER 2001: 775-780

CONSTRUCTION AND OPERATION OF A VOLTAGE-CONTROLLED OSCILLATOR

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(Received 26 June 2000 ; Revision accepted 17 April, 2001)

ABSTRACT

A voltage - controlled Oscillator whose frequency changes are controlled by corresponding changes in the voltage of oscillation has been constructed. The input modulated voltages of oscillation produce different frequencies as seen from the results. By varying the input voltage in steps from zero towards 24 volts frequencies ranging from 600Hz (0.3 f_o) to 2.0 kHz (1.0 f_o) were obtained where f_o is the fundamental frequency. Observations revealed that in the region of low frequencies (that is frequencies lower than the fundamental) input voltage to the μA741 IC op-amp leads its output until a voltage, which increases from zero towards 24volts. At 24V, the input and output voltages are in phase producing the fundamental frequency. For frequencies higher than the fundamental frequency the input lags behind the output from a voltage of 24V towards zero.

Keywords: Voltage-controlled Oscillator, fundamental frequency, feedback, integrated circuit.

1.0 INTRODUCTION

A voltage-controlled oscillator is a circuit that provides a varying output signal (typically of square wave or triangular waveform) whose frequency can be adjusted over a range controlled by a dc voltage according to Boylestad *et al*, (1997).

Vassos et al (1972), defined an oscillator as an electronic device that converts power from a direct current supply into an alternating current. Menkiti *et al*, (1996) also defined oscillators as devices which provide a.c output when the input is a d.c. source without a switching, rotatory, or vibratory mechanism.

The construction of a voltage-controlled oscillator serves as a means of obtaining an adequate source of test signals for measurement procedures as this type of oscillator in more stable and quicker in action than those employed in television, video and expensive radio sets.

2.0 THEORY.

The values of the components used in this work were estimated with the aid of certain equations. The VCO with the actual component values used is shown in Fig. 1. When a capacitor C_1 is charged from zero volts towards a voltage

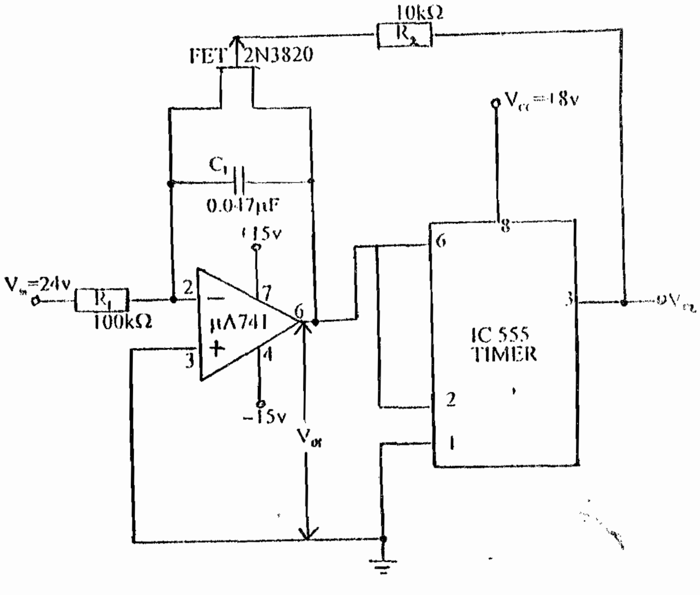

Fig. 1 The constructed VCO with component values

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via a resistor R_1, the capacitor voltage rises exponentially according to the equation,

$$V_{cc} = V_{in} e^{(t/R_1C_1)} \quad \text{............(1)}$$

Differentiating equation (1) with respect to time, t, and setting t = o gives

$$\frac{dv_{cc}}{dt} = \frac{V_{in}}{R_1C_1} \quad \text{..................(2)}$$

Integrating equation (2) with respect to time yields

$$V_{cc} = \frac{T_oV_{in}}{R_1C_1} \quad \text{.......................(3)}$$

Boylestad, et al (1997), and Graf (1991) estimated the period of oscillation as

$$To = R_1C_1 \frac{V_{cc}}{V_{in}} \quad \text{.................(4)}$$

Hence, the frequency of oscillation is

$$f_o = \frac{1}{T_o} = \frac{3V_{in}}{R_1C_1} \quad \text{.........(5)}$$

The output frequency of oscillation was estimated to be 1.91 kHz using V_{in} = 24V, R_1 = 100k , C_1 = 0.047µF and V_{cc} = 8v in equation (5). Rewriting equation (4) we get

$$R_1 = \frac{1V_{in}(nom)1}{V_cC_1f_o(nom)} \quad \text{.........(6)}$$

R_1 was calculated to be 95.8k using V_{cc} = 8 8v, $V_{in\,(nom)}$ = -24v, V_c = 5.33V (0.667 V_{cc}), C_1 = 0.047µF and $f_{0(nom)}$ = lkHz from equation (6). The choice of R_2 was not critical so it was chosen to be 10k from Weber (1977).

The capacitor C_1 was chosen from Yunik (1973) using

$$C_1 = \frac{T_p}{R_{on}} = \frac{1}{f_{o(\max)}R_{on}} \quad \text{......(7)}$$

Where R_{on} the on resistance of the fiel effect transistor used in this work was obtained from Simmon (1991) as

$$R_{on} = \frac{V_p}{2I_{DSS}} \quad \text{...................(8)}$$

Thus using V_p = 8V and I_{DS} = 0.3mA Ron was estimated to be 13.3kΩ. using f_o = 1.9kHz and Ron = 13.3kΩ calculated from equation (5) and (8) respectively, produced the capacitance of the capacitor to be 0.04µF. Though the actual value used was 0.047µF since it is approximately equal to the theoretically calculated value.

3.0 MATERIALS AND METHODS

In this work two integrated circuits, namely µA741 op-amp and the 555 timer chips, were used to produce simultaneous triangular and square wave output signals respectively.

3.1 MATERIALS

3.1.1 THE 555 IC TIMER DEVICE.

The 555-timer device consists of two comparators A and B, a flip-flop circuit, a transistor discharge path and the output. The two outputs of the comparators are fed into the flip-flop circuit and its final Output is obtained from terminal 3. Q and $\overline{Q}$ are the outputs from the flip-flop unit.

There are eight connecting pins on the device, four on each opposite side. The 555IC is shown in Fig. 2.

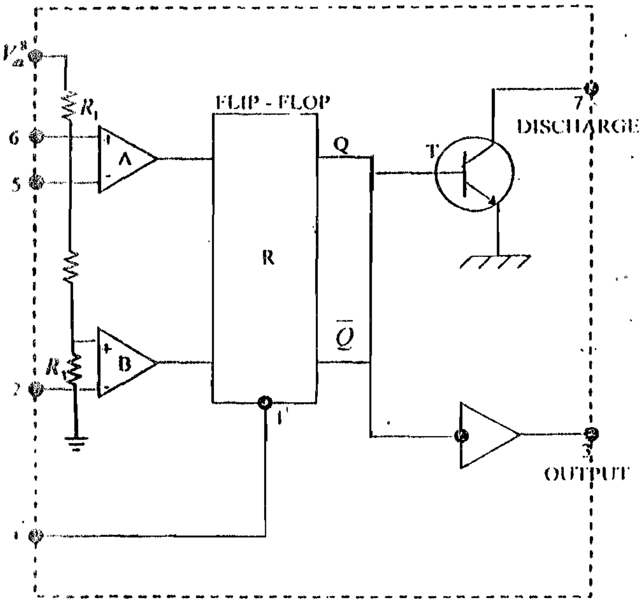

Fig. 2: Internal arrangement of the 555 timer

3.2 THE OP-AMP μA741 IC.

Fig. 3 shows the general purpose μA741 op-amp. Like the 555 IC, it has eight connecting pins. Pin 8 is not connected. It is the overload protection on the input and output of the device when the common mode range is exceeded.

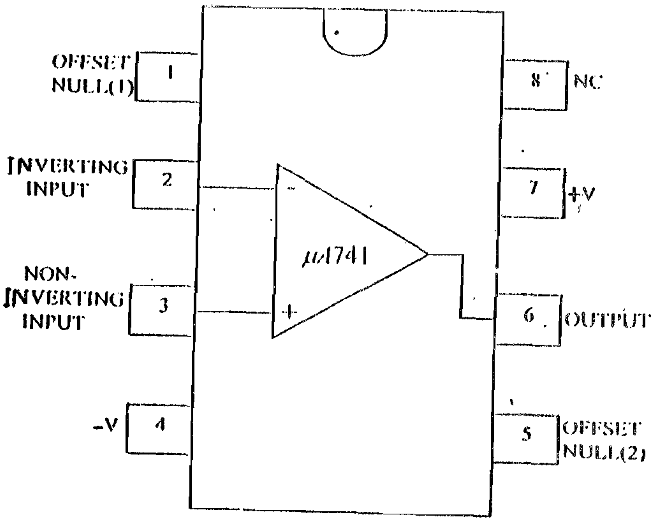

Fig. 3: μA741IC 8-pin dual-in-line package

3.2 METHODS

The printed circuit board forms the chassis on which all other components such as the FET 2N3820, capacitor C_1 = 0.047μF, resistors R_1 = 100k Ω and R_2 = 10kΩ were mounted and soldered as shown in Fig. 1. Components such as μA741 IC and NE555V timer device were fixed in the 8-pin IC sockets before being mounted and soldered on the printed circuit board to prevent the IC_S from possible damage due to excessive heat from the soldering iron.

Pins 4 and 7 of the μA741 op-amp were used to power the VCO, with a ±15V d.c. delivered from the constructed dual rail regulated power supply. Pin 4 was fed with the -15V d.c. whereas pin 7 was used for the +15v d.c.

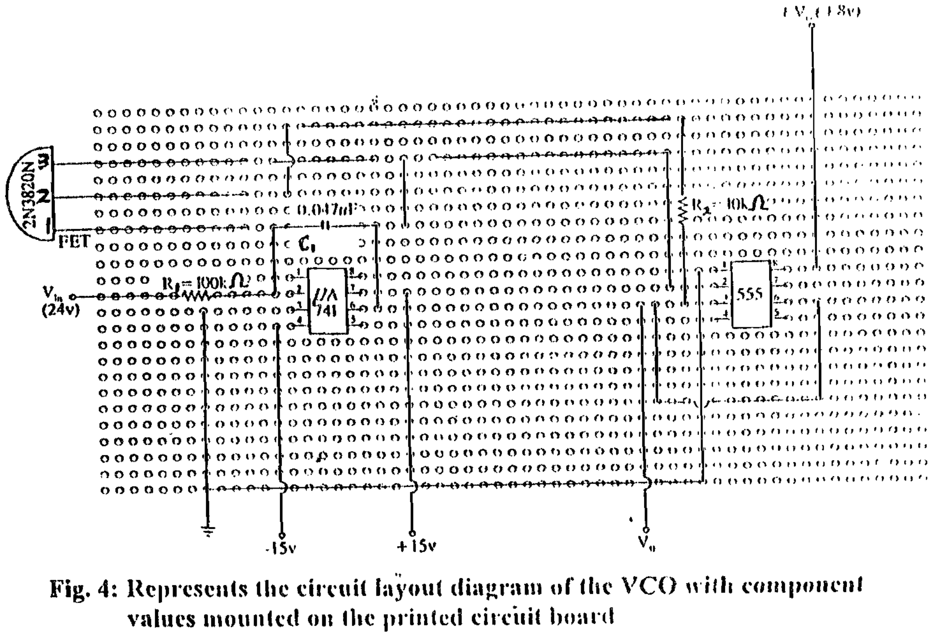

Fig. 4: Represents the circuit layout diagram of the VCO with component values mounted on the printed circuit board

The op-amp μA741 was wired as an integrator with the time constant set by the product R_1 and C_1. Similarly, the 555 IC was wired as a comparator to produce a square wave output. Pin 6 of this op-amp produced the first output stage which is a triangular waveform. Pin 3 of the 555 timer produced the square wave output.

The circuit layout diagram shown in Fig. 4 helps in providing the knowledge of the position of a particular components and how it is linked with others components in the circuit.

A d.c. dual rail power supply of ±15V was constructed to enhance the powering of the μA741 IC op-amp using a 15V bridge rectifiers (100w), two 220μF, two 47μF and two 1500pF filtering capacitors as well as two power transistors TIP33 and TIP34 for the stabilization. Fig. 5 shows the circuit diagram of the constructed power supply.

TABLE 1:

EXPERIMENTAL DATA; f_o represents the fundamental Frequency which is 2.0 KHz

Frequency f (KHz)	$\frac{f}{f_o}$	Output voltage (v) V_o
0.6	0.3	1.0
1.0	0.5	1.5
1.4	0.7	2.2
2.0	1.0	2.8
3.0	1.5	2.1
3.8	1.9	1.6
5.0	2.5	1.1
10.0	5.0	1.0
12.0	6.3	1.0
16.0	8.0	1.0

4.0 OPERATION AND CALIBRATION

Different voltages of oscillation were observed. These, controlled by the VCO network within the positive feedback loop, were monitored and measured with the aid of a cathode ray oscilloscope. Pins 2 and 6 of the 555 timer were connected together to pin 6 of the μA741 op-amp to allow the capacitor C_1 to charge and discharge between the threshold and trigger levels of ⅔ V_{cc} and ⅓V_{cc} respectively.

The voltage-control was achieved by the way Fig. 1 was wired to make the circuit behave like a high pass filter and a low pass filter simultaneously. Thus all frequencies were passed. At lower frequencies the high pass filter dominates due to the high reactance of the capacitor. The low pass filter in turn dominates as frequency increases and the reactance of this capacitor decreases.

The output frequency and amplitude were calibrated using an oscilloscope to give an accuracy of ±3% for both time and amplitude.

To maintain the stability of the output frequency a stabilized power

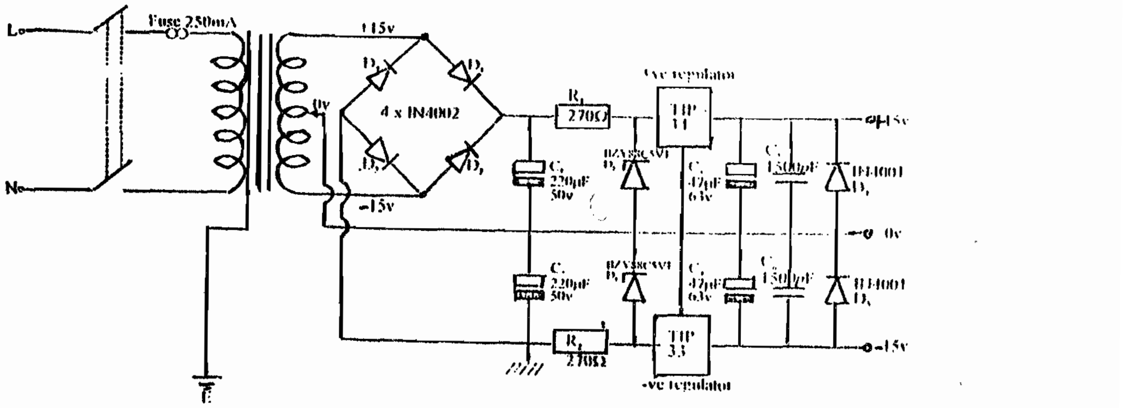

Fig. 5 Shows circuit diagram of a Regulated Dual Power Supply with Component values.

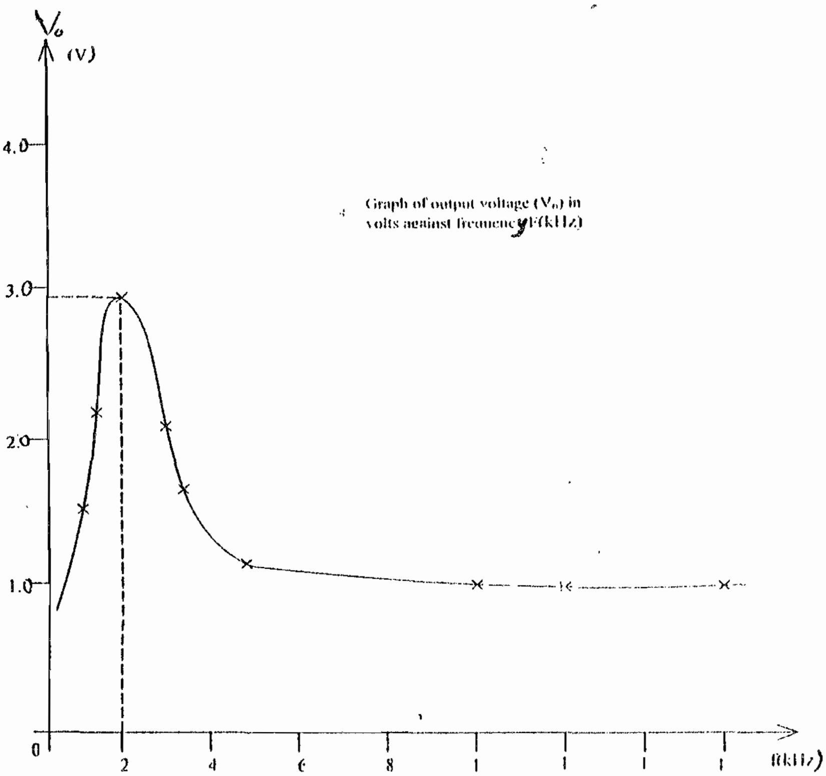

Fig. 6 Voltage-frequency response curve of the VCO.

supply was built to minimize the drift from the resonant frequency of the oscillator.

4.1 RESULTS AND DISCUSSION.

The results obtained from the experiment performed using the VCO are shown in Table 1.

It was observed that the voltage of oscillation between the input to the μA741 IC and its output back to the positive feedback was varied as well as the frequency of oscillation. This supports Millman and Halkias (1967) that the frequency at which a sinusoidal oscillator will oscillate is that for which the phase angle between the input to the op-amp 741 IC and its output to the positive feedback is zero or an integral multiple of 2π (Backhausen condition).

The output frequency of a precision voltage-controlled oscillator is lkHz. Graf(1991). Comparing this value with the one constructed in this work which is 2kHz, we find that they are of the same order. The variation may be due to the slight difference in the component values used for this work with the theoretically estimated values.

From equation (5), (the frequency of oscillation) it can be seen that by varying the input voltage-controlled network in the positive feedback loop, the voltage between the input and output varied. This shows that as the voltage varied, the frequency of oscillation of the VCO also varied. Fig. 6 gives the graph of the output voltage (v) against multiples and sub-multiples of the fundamental frequency f_o. The voltage-frequency response is a resonance curve with voltage increasing initially with frequency and peaking at resonant frequency

f_o. At frequencies higher than the fundamental frequency f_o the voltage begins to fall again towards zero.

4.2 CONCLUSION

The process of constructing a VCO just like that of any other electronic device is interesting but not quite easy. This is due to variations existing between theoretically calculated values and actual component values used in the construction of the circuit. These variations pose problems in a situation where the researcher is a novice in the field of electronics. For instance, the fundamental frequency of the VCO was measured to be 2.0kHz on the oscilloscope while its theoretically calculated value from components (R_1 = 100kΩ, C_1 = 0.047μF, V_{in} = 24V and V_{cc} = 8V) was 1.9lKHz. This error is mainly due to the tolerances of the components.

The results obtained reveal that within the frequency range covered varying the voltage of oscillation controls the oscillator frequency.

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