Lab-Report
Analogue Communications

Frequency Modulation

Name: Dirk Becker
Course: BEng 2
Group: A
Student No.: 9801351
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UNIVERSITY *of* EAST LONDON

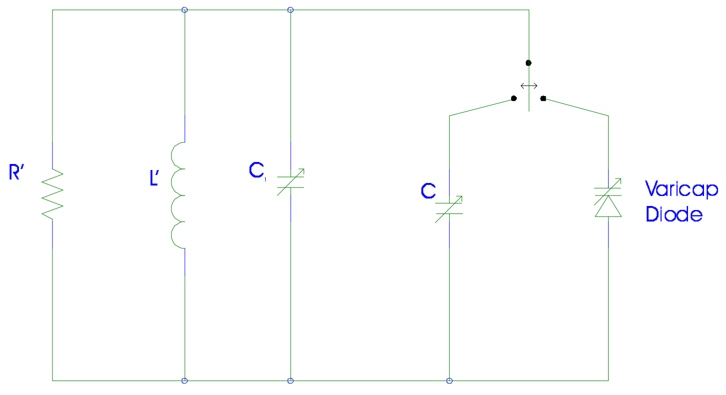
1. Contents

2. Introduction

Frequency modulation was first introduced by Edwin Howard Armstrong in the early 1930s. It took several years before the advantages of FM were fully discovered. Frequency modulation needs a large bandwidth compared with Amplitude Modulation when good results should be obtained. Frequency modulation is widely used since the late 1940s.
The difference between Amplitude modulation is, that instead of varying the amplitude of a carrier the carrier frequency itself is shifted and carries the information. The amplitude of the carrier is held constant. So at the receiver the waves can be amplified very much, clipped and any distortion in amplitude will not cause hearable distortions → The SNR of FM is much better than the one of AM.

3. Frequency Modulation Systems

A simple frequency modulation system is shown in the following figure.

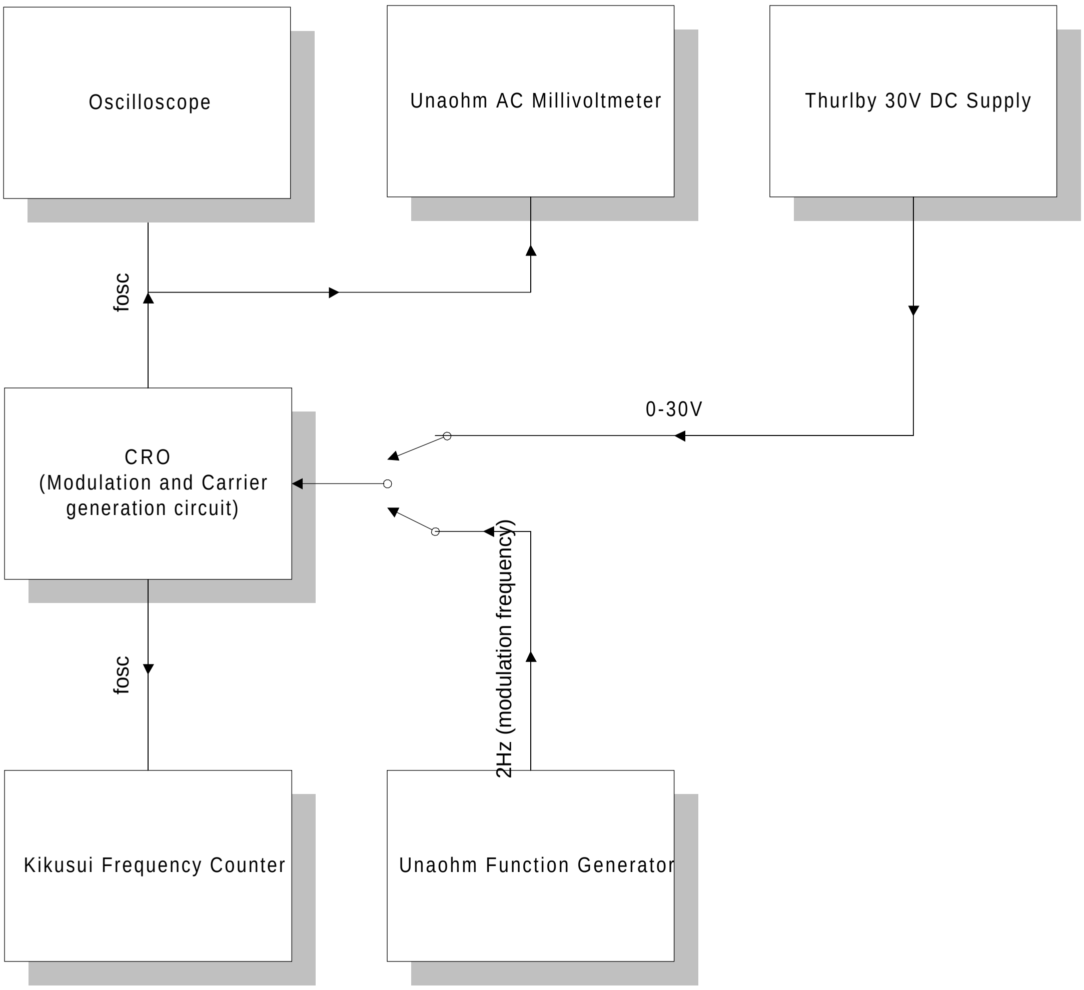


The left part of the circuit has got a fixed resonant frequency f_0. By applying the right part of the circuit it is possible to change this frequency f_0 by either changing the value of C or the varicap diode by applying a suitable voltage to it.
The change of a frequency according to an applied signal is known as frequency modulation. The Lab should give an introduction to these frequency modulation systems.

4. Lab procedure

a) Lab equipment

The following figure shows a diagram of the used Lab equipment.

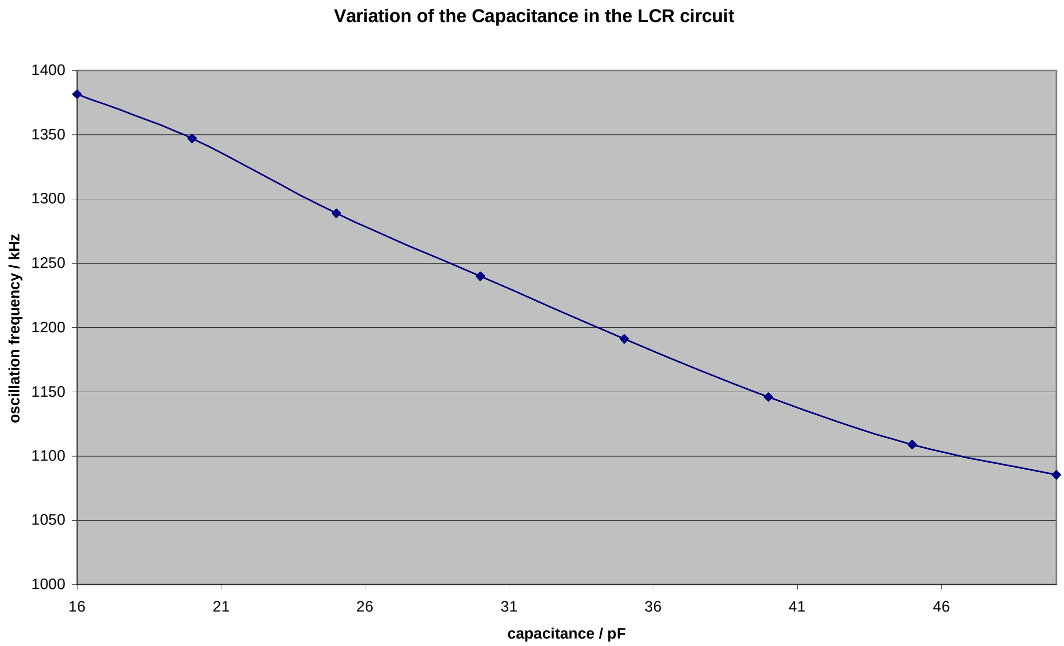


The CRO unit generates the carries frequency and contains a built in varicap diode and a calibrated capacitor with which the carrier frequency can be either manually or electronically be changed by applying a voltage to the varicap. A Thurlby 30V DC power supply and a Unaohm frequency generator can generate an appropriate voltage therefore.
The carrier frequency could be checked in it's frequency and amplitude by means of an oscilloscope, a counter and an AC – Millivoltmeter.
The attenuator of the counter had to be enabled because otherwise the counter is a load for the CRO and the output voltage and frequency could not be read out exactly. As gate time 0.1s was used, in order to readout the measured frequencies properly. Counter are very exact electronic measuring instruments. They have usually errors in the area of $<10^{-5}$ from the measured value.

b) Carrier frequency oscillator

First part of the Lab was to change the calibrated capacitor and to obtain a plot of the carrier (resonant) frequency vs. the parallel capacitance.

C/pF	f/kHz
16	**1381,69**
20	**1347,26**
25	**1288,93**
30	**1239,94**
35	**1191,12**
40	**1145,94**
45	**1109,01**
50	**1085,22**



The variance of the capacitance C results in a nearly linear variance of the resonance frequency.

c) **Determination of L' and C_T**

With the different measured values of C and f_o it is possible to determine the values of C_T and L'.

$$f_0^2 = \frac{1}{4\pi^2 L'(C_T + C)}$$

$$f_{01}^2 = \frac{1}{4\pi L'(C_T + C_1)} \quad \Rightarrow \quad L' = \frac{1}{4\pi^2 (C_T + C_1) f_{01}^2}$$

$$f_{02}^2 = \frac{1}{4\pi L'(C_T + C_2)} \quad \Rightarrow \quad L' = \frac{1}{4\pi^2 (C_T + C_2) f_{02}^2}$$

$$\frac{1}{4\pi^2 (C_T + C_1) f_{01}^2} = \frac{1}{4\pi^2 (C_T + C_2) f_{02}^2}$$

$$C_T f_{01}^2 + C_T f_{02}^2 = C_2 f_{02}^2 + C_1 f_{02}^2$$

$$C_T = \frac{C_2 f_{02}^2 - C_1 f_{01}^2}{f_{01}^2 - f_{02}^2} = \frac{50\text{pF} \times (1085\text{kHz})^2 - 20\text{pF} \times (1347\text{kHz})^2}{(1347\text{kHz})^2 - (1085\text{kHz})^2}$$

$$\underline{\underline{C_T = 35\text{pF}}}$$

$$L' = \frac{1}{4\pi^2 (C_T + C_2) f_{02}^2} = \frac{1}{4\pi^2 (35\text{pF} + 50\text{pF}) x (1085\text{kHz})^2}$$

$$\underline{\underline{L' = 253.14\mu\text{H}}}$$

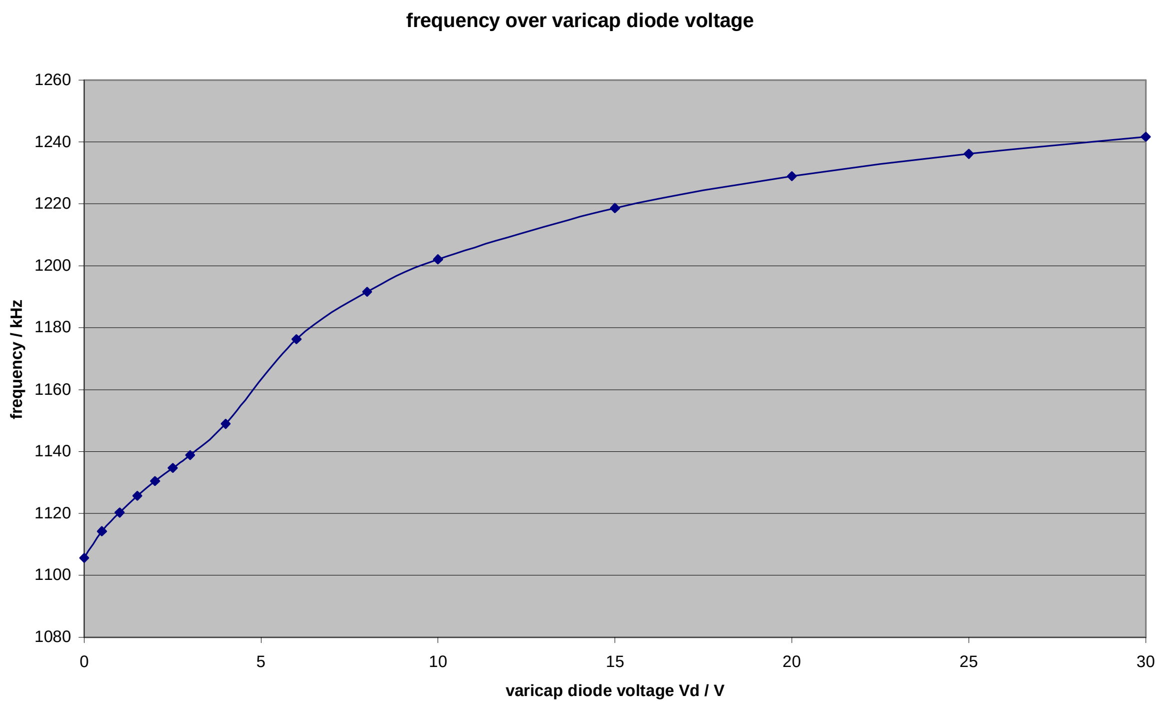
The error of this calculated values depends on the precision of the measured values of f_0 and the precision of the calibrated capacitor.

d) Carrier frequency variation with varicap diode

Varicap diodes are semiconductors, voltage dependent, variable capacitors. Their mode of operation depends on the capacitance that exists at the p-n junction when the element is reverse biased. Under reverse bias conditions there is a region of uncovered charge on either side of the junction which leads to a capacitance.
The Varicap was used instead of the calibrated capacitor. A plot of the voltage applied to the Varicap vs. frequency and amplitude was obtained.

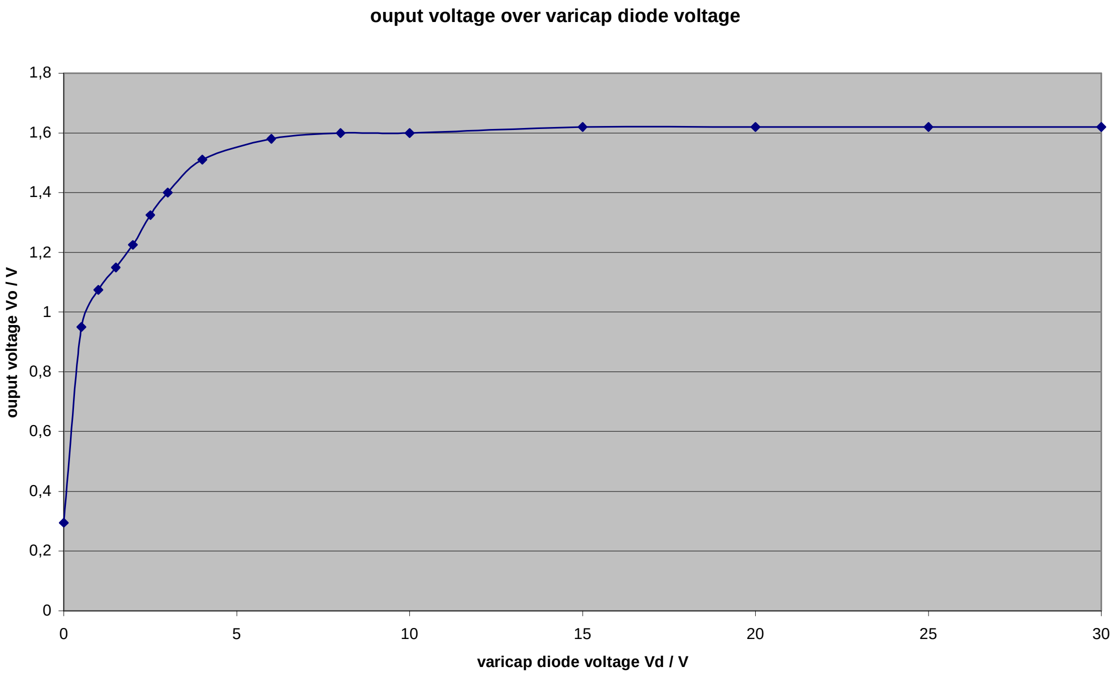
i. Frequency vs. Varicap voltage

Vd/V	f/kHZ
0	**1105,62**
0,5	**1114,3**
1	**1120,33**
1,5	**1125,73**
2	**1130,46**
2,5	**1134,74**
3	**1138,88**
4	**1148,95**
6	**1176,35**
8	**1191,6**
10	**1202,07**
15	**1218,67**
20	**1228,96**
25	**1236,18**
30	**1241,65**



ii. Amplitude vs. Varicap voltage

Vd	Vo
0	**0,295**
0,5	**0,95**
1	**1,075**
1,5	**1,15**
2	**1,225**
2,5	**1,325**
3	**1,4**
4	**1,51**
6	**1,58**
8	**1,6**
10	**1,6**
15	**1,62**
20	**1,62**
25	**1,62**
30	**1,62**



The output voltage is not at a stable level when only small voltages (low frequencies) are applied to the varicap. This results from the inner structure of the CRO.

5. Modulator operation

When a signal with appropriate amplitude and frequency is applied to the varicap the CRO circuit works as a frequency modulator. The modulation frequency was a 2Hz sinewave with 8.8V offset and an amplitude of 5.2 volts. The resulting modulated frequency deviated between ~1180KHz and 1217kHz. When the offset voltage was to low, the CRO generated amplitude modulation, because the CRO was not able to supply a stable output voltage below V_D=5V.
With the low modulating frequency of only 2Hz the modulating output could be obtained very well on the oscilloscope.

6. Conclusion

The value of C_T must be in the area of C, because otherwise the carrier frequency can not be varied very much. With the values of C and C_T the value of L' is predetermined by the equation for the resonant frequency.
The capacitance of the varicap must be in the same area than the capacitance of the calibrated capacitor C, to obtain the same resulting frequencies (ca. 1100kHz-1400kHz).
High quality FM modulators must have a high linearity to prevent distortions. Also the amplitude of the output must be held constant, because no amplitude modulation must occur.

7. Related Internet Sites (History of FM)

http://home.att.net/~katzmann/
http://members.aol.com/jeff560/fm5.html
http://www.webstationone.com/era/html/armstrong.htm
http://members.aol.com/jeff560/fm5.html