EXPERIMENT E3: RADIO FREQUENCY OSCILLATORS

Related course: KIE2004 (Electronic Circuit II) or KEET3206 (Electronics Communications)

OBJECTIVES:
To analyse radio frequency oscillators

EQUIPMENT:
Oscilloscope; function/signal generator; DC power supply; breadboard; multimeter; jumpers; OpAmp 741 (1 unit); n-Channel JFET 2N3819 (1); diode 1N4007 (1); resistors: 10kΩ (4), 1kΩ (1), 100kΩ (1); capacitors: 0.01uF (2), 0.1uF (1), 10uF (1), potentiometer: 50kΩ (2) and 1kΩ (1)

INSTRUCTIONS:
1. Record all your results and observations in a log book
2. Follow the demonstrator's instructions throughout the experiment

REFERENCE(S):
Refer to the main references of KIE2004 or KEET3206

TESTS:
TEST 1: WIEN BRIDGE OSCILLATOR
TEST 2: AUTOMATIC GAIN CONTROL

INTRODUCTION:

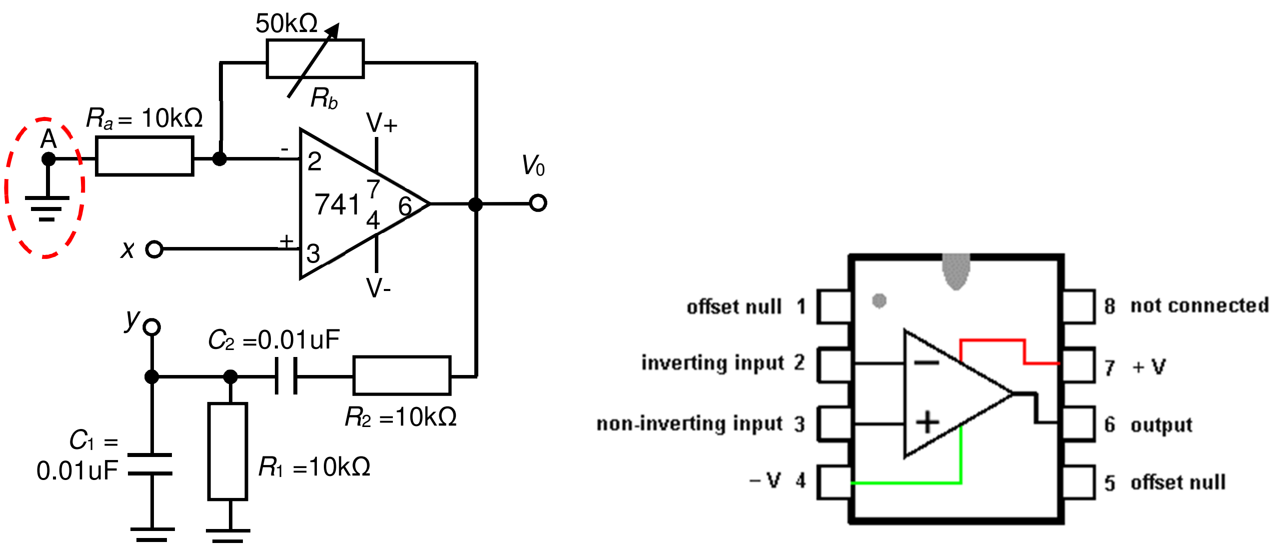
Oscillators are circuits that produce specific, periodic waveforms such as square, triangular, sawtooth, and sinusoidal. They generally use some form of active device, lamp, or crystal, surrounded by passive devices such as resistors, capacitors, and inductors, to generate the output. Op-amp sine-wave oscillators operate without an externally-applied input signal. Instead, some combination of positive and negative feedback is used to drive the op amp into an unstable state, causing the output to cycle back and forth between the supply rails at a continuous rate. The frequency and amplitude of oscillation are set by the arrangement of passive and active components around a central op amp.

A Wien bridge oscillator (in Figure 1a) is a type of electronic oscillator that generates sine waves. It can generate a large range of frequencies. The oscillator can also be viewed as a positive gain amplifier (R_a and R_b loop) combined with a bandpass filter (formed by R_1, R_2, C_1 and C_2) that provides positive feedback. Automatic gain control, intentional non-linearity and incidental non-linearity limit the output amplitude in various implementations of the oscillator. In Figure 1, when R_1=R_2=R and C_1=C_2=C, the frequency of oscillation is given by $f = 1/(2\pi RC)$.

TEST 1: WIEN BRIDGE OSCILLATOR

1. Connect the circuit as shown in Figure 1a. Set V+ (at pin 7 of OpAmp 741) to 10V DC and V- (pin 4) to -10V DC. Connect point A to the ground.
2. Connect a sinusoidal signal source from a function generator to terminal *x* (pin 3) and observe the waveform at point *y* with an oscilloscope. You can set any amplitude and frequency of the sinusoidal signal as long as you can observe a signal at point y.
3. Adjust R_b (50kΩ potentiometer) so that an undistorted waveform is observed at point *y*.

4. Vary the frequency of the sinusoidal signal and locate the frequency at which the waveform at point *y* is exactly in phase with the one at point *x*. Record the frequency.
5. Adjust R_b until the two amplitudes are exactly equal.
6. Remove the sinusoidal signal and connect point *x* to point *y* with a wire/jumper.
7. The circuit should oscillate, if it does not repeat steps 1 through 6, but adjusting R_b so that voltage at *y* is 5 or 10% larger than that at *x*.
8. Record the frequency of oscillation at the op-amp output V_0 (pin 6) and sketch the waveforms at V_0 and pin 2. Record their peak to peak values.
9. Measure the value of R_b that you have set without changing its setting.



(a) WIEN bridge oscillator (b) OpAmp 741

Figure 1

TEST 2: AUTOMATIC GAIN CONTROL

It can be observed that the output waveform of the WIEN Bridge oscillator is distorted. This is due to the circuit poles must be placed just to the right of the imaginary axis for the oscillation to build up. The amplitude then builds up until the nonlinearity of the amplifier reduces the small signal gain sufficiently to move the poles back to the left half plane. The next experiment will be using FET in the voltage controlled resistance region, which automatically senses the output voltage peak level and adjusts the gain to just precisely place the poles on the imaginary axis.

PROCEDURES:

1. Replace the section in dashed-line in Figure 1a with the part shown in Figure 2.
2. Adjust *R* (1kΩ potentiometer) so that the movable contact is close to the bottom. The resistance between the movable contact and ground must be low (few hundreds).
3. Adjust R_b to obtain oscillation with a minimum amount of distortion. Measure its value.
4. Slowly vary *R* and observe V_0 (pin 6) with the oscilloscope (V_0 can be adjusted to any desired value between 2V and approximately 15V peak to peak. The output should be an almost undistorted sinusoid of constant frequency).

5. Measure the peak to peak value of V_0 and at pin 3. The value of R_x should be measured for 5 different values between the minimum and maximum values of V_0.
6. Replace C with a larger capacitor in the 5 to 10uF range. Repeat steps 1 to 5.

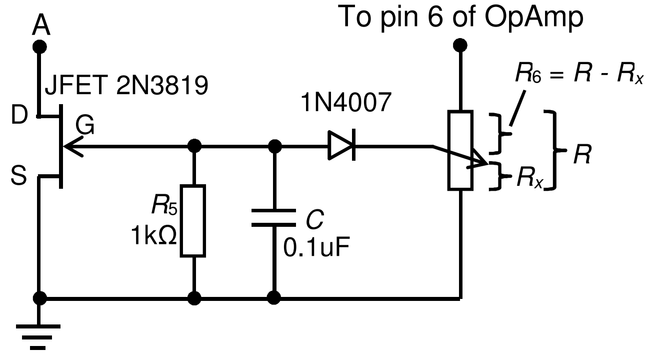


Figure 2: Automatic gain control circuit

DISCUSSION:

1. Derive the loop gain $T(s)$ for the circuit of Figure 1(a) in terms of R_1, C_1, R_2, C_2 and A. Evaluate for $s = j\omega$ and find the frequency ω_0 at which L $T(j\omega)$ = 0°. Then, find the required value of voltage gain A. Using the measured values of R_1, C_1, R_2, C_2, evaluate these values numerically. Compare the theoretical value of $f_0 = \omega_0/2\pi$ with the experimental value. Also derive for A. Note that the experimental value for A can be obtained by taking the ratio of measured V_{pp} to V_{Fpp} or from measured $1+(R_b/R_a)$.
2. Derive the peak output amplitude for the WIEN Bridge oscillator with the automatic gain control as a function of R_6. Assume that the peak detector is ideal, that is V_G=$V_{0(peak)}$ is a DC voltage (this is equivalent to assuming that R_GC_G time constant is very large compared to the oscillation period). Also, assume that the FET is ideal and $r_{DS}=r_{DS(on)}/[1-(V_{GS}/V_p)]$. Draw a graph of V_{0pp} versus R_x for theoretical and experimental results.

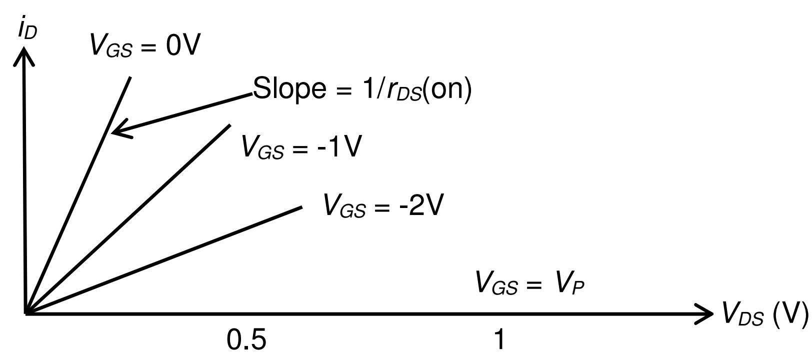


Figure 3: Voltage-controlled resistor (VCR) characteristics of N-channel FET

END OF EXPERIMENT