Electronics

Oscillator with the 555 chip

Problem 1.- To control a coffee bean shaker, an oscillator is required with a TTL output with 20% duty-cycle and two frequencies: 200Hz and 250Hz that can be selected with a switch. Design a circuit with these specifications.

Solution: One possibility is using the 555 chip in the astable configuration. This chip already has an output with the required TTL standard, but the problem is that the duty cycle is always more than 50%. To solve this problem we could generate the signal with 80% duty cycle and then invert it using a NOT gate, which will give us the 20% needed.

Since the resistors determine the duty-cycle we could leave them fixed and use the switch to change the capacitance to change from 200Hz to 250Hz.

To obtain 80% $$duty-cyle = \frac{R_1 + R_2}{R_1 + 2R_2} = 0.8 \rightarrow R_1 = 3R_2$$

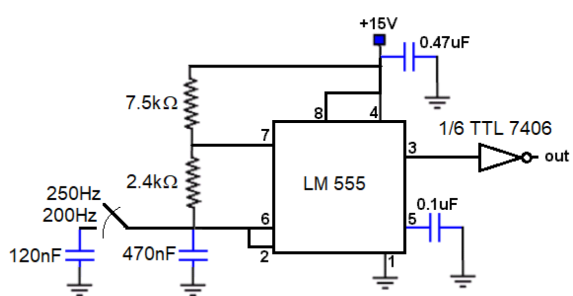
For a frequency of 250Hz the period is 4ms, so

$$T = \ln(2)(R_1 + 2R_2)C_A = 4ms \rightarrow C_A = \frac{4ms}{\ln(2)(R_1 + 2R_2)}$$

Many different combinations of resistors and capacitors could be used, for example with the following standard values

$$C_A = 470nF$$
$$R_1 = 7.5k\Omega$$
$$R_2 = 2.4k\Omega$$

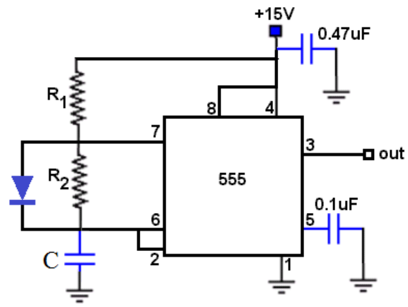
Instead, for 200 Hz, the period will be 5ms and the capacitor needs to be 25% larger, which we can get by adding 120nF in parallel as shown below.



Notice that we are using one of the six NOT gates that come in a TTL7406 chip.

There are other ways of solving this problem. An interesting design is to use the 555 chip in the astable configuration to generate the required frequency, but then using the falling edge of the output to trigger other 555 in the one-shot configuration to get any arbitrary duty cycle. For example 20% of the cycle at 250Hz is 0.8ms and 1ms for 200Hz. This has the inconvenience that we would need to switch two capacitors and we need two 555 chips.

Another idea is to modify the astable configuration with a diode in parallel with the discharge resistor R_2, as shown below.



In this configuration the discharge happens through R_2 as normal, but the charging is only through R_1, since the diode shorts R_2. This way the duty cycle can be less than 50% since:

$$duty-cyle = \frac{R_1}{R_1 + R_2}$$

However, you should be careful that the equation for the frequency is also different than the standard configuration:

$$f = \frac{1}{\ln(2)(R_1 + R_2)C}$$

There is also a detail that you should be mindful of in this case: When you charge the capacitor though R_1 the 0.7V voltage drop in the diode has to be subtracted from the source voltage and the time to reach $2/3V_{cc}$ would be longer. This error depends on V_{cc}, for example for 15V it is de 7% and for 5V it is 23%! So be careful if using this scheme.

Problem 2.- Design a circuit that uses the 555 multi-vibrator to generate a 440Hz square wave with a duty cycle of 66.66%.
Select resistors and a capacitor that make sense. Do not use farads or multi mega-ohm, or tiny resistors in the discharge circuit.

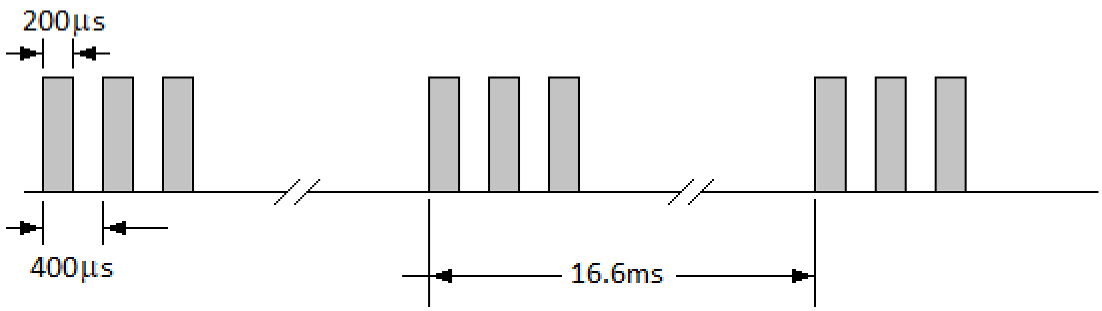
Solution: Making $R_1 = R_2$ assures us a 66% duty cycle.

We want: $$440Hz = \frac{1}{\ln(2)(R_1 + 2R_2)C}$$

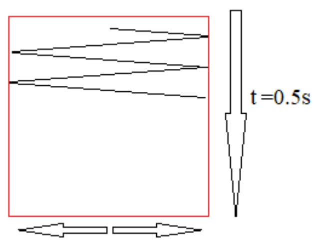
We can choose C = 1μF and $R_1 = R_2 = 1.1\ k\Omega$

Problem 2a.-Design an oscillator of frequency 4.4kHz and 75% duty cycle based on a 555 chip.

Problem 3.- For an application in which a power electronic device has to be triggered by a train of pulses we need to generate the signal shown below. Design a circuit that produce this signal.



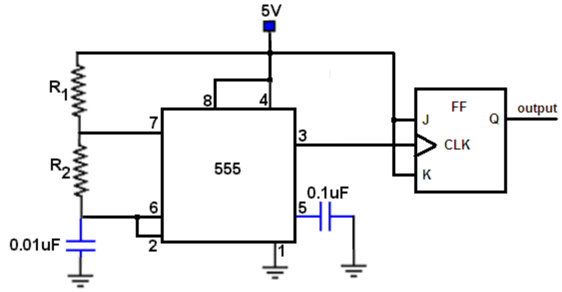
Problem 4.- In an equipment to treat surfaces it is required to scan a very small square area by moving a probe on the surface with two piezoelectric devices that are perpendicular to each other.
The sweep in one axis has to be done in 0.5s, while the other axis sweeps 50 times in this time as indicated in the figure below.



Design circuits that generate the control signals for the piezoelectric devices that work with inputs of 1Vpp.

Problem 5.- Design a 10 kHz oscillator with 50% duty cycle.

Solution: Notice that using a 555 alone in its usual configuration it is not possible to reach 50% duty cycle because the value of: $\frac{R_1 + R_2}{R_1 + 2R_2}$ is always greater than 0.5, although you can get really close.
In order to get a 50% duty cycle we can divide the signal from the 555 oscillator by 2 using a JK flip-flop. Then, the oscillator will need a frequency of 20 kHz. The design will look as follows:



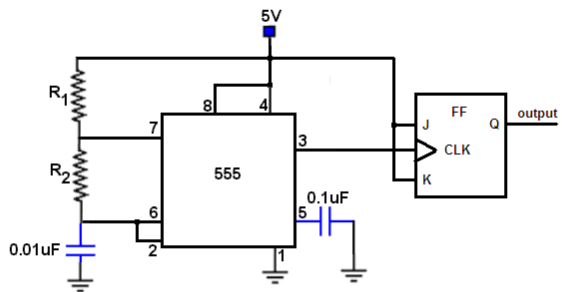
To get 20 kHz we need:

$$20{,}000Hz = \frac{1}{0.6931(R_1 + 2R_2)(0.01\times10^{-6}F)} \rightarrow R_1 + 2R_2 = 7{,}213\Omega$$

We can approximate this value with R_1 = 2.8 kΩ and R_2 = 2.2 kΩ.

Problem 5a.- For experiments that are very sensitive to noise we can employ the technique of "lock-in" amplification. Design a square wave oscillator that works at 40kHz and 50% duty cycle that we will use as reference signal for this application.

Solution: The solution can be accomplished with the chip 555 in an astable configuration; however, for the signal to have a 50% duty cycle, we can generate 80kHz and divide the signal by two with a JK Flip-Flop as in the following diagram:



To get 80 kHz we need: $80kHz = \frac{1}{0.693(R_1 + 2R_2)(0.01\mu F)} \rightarrow R_1 + 2R_2 = 1.8\text{k}\Omega$

This can be done with R_1 = 800Ω and R_2 = 500Ω.