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10-13-2024

ECEN 5730

Lab 13/14 report

**Lab 13**

**Introduction:**

In this lab a ring oscillator was constructed via daisy-chaining the inputs and outputs of several hex inverters together. Afterwards, one of the connections between the ring-oscillator was replaced with a 1MΩ resistor to increase the propagation time of the circuit. Moreover, this circuit was then improved upon by incorporating a crystal oscillator into the circuit. Afterwards, this circuit was further improved with the addition of filter capacitors, to filter out higher order modes of oscillation.

**Standard ring oscillator:**

The standard ring oscillator works by feeding an inverter’s output back into its input. Because an inverter inverts the signal read at its input, this results in the circuit oscillating between one and zero on both terminals. The delay time or propagation delay between switching from zero to one can be increased by adding in more inverters between the original inverter’s input and output, as seen below.

**A close up of a circuit board

Description automatically generated**

**Circuit diagram:**

Here is the diagram of the ring oscillator, the colors correspond to the actual wiring on the built circuit.

**A diagram of a diagram

Description automatically generated**

**Ring oscillator scope cap:**

When constructing this circuit, I forgot to add in any decoupling capacitors which explains the noise in this scope-cap.

A screen shot of a computer

Description automatically generated

**Ring oscillator measurements:**

Below is the measured frequency of the ring oscillator. After the original circuit was constructed, a 1MΩ resistor replaced one of the connections between one of the hex inverters. Since this reduces the current from one terminal to the next, this causes the propagation delay to be reduced.

**A screenshot of a computer

Description automatically generated**

**Crystal-oscillator circuit layout:**

The middle circuit is the modified version of the ring oscillator circuit. You can also observe the 1MΩ replacement on the previous circuit.

Crystal ring oscillators oscillate based on the frequency at which the impedance is the lowest, later in the report the resonance frequency of the crystal is revealed to be around 16 MHZ, which when measured the Crystal ring oscillator is found to be around 20MHZ. There is a 4MHZ difference, but the two figures are approximately the same. This is because there is the least amount of distortion or reduction from vin to vout when at the resonant frequency. One could consider a voltage loss due to a crystal filter to be somewhat analogous to the voltage loss observed across a resistor or some amount of impedance, which is why the two frequencies tend towards each other.

**A white circuit board with wires and wires

Description automatically generated**

**Circuit diagram:**

Below is the schematic used in the physical circuit above.

**A diagram of a circuit

Description automatically generated**

**Crystal resonant frequency:**

The bench oscilloscope used features functionality which allows one to measure the bode plot of any given circuit. When applied to the crystal, the following resonant frequency was observed.  
It appears at 16 MHZ the highest gain is observed.

**A screen shot of a computer

Description automatically generated**

**Crystal oscillator scope cap:**

**A screen shot of a graph

Description automatically generated**

**Crystal oscillator scope cap with filter capacitors added:**

Notice how the amplitude of the waveform has reduced by .4v. By adding in the filter capacitors higher order modes of operation are suppressed. This typically means that the oscillator will oscillate at higher frequencies, but there was no observed effect other than the reduction in amplitude. With more time it might be possible to troubleshoot this discrepancy between the data and theory.

**A screen shot of a computer

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**Crystal oscillator with filter cap circuit schematic:**

A diagram of a circuit

Description automatically generated

**Collected data:**

**A screenshot of a white sheet with black text

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**Conclusion:**

This lab was an excellent demonstration of oscillator technology, and how oscillators can be modified in certain ways to provide more optimal behavior. This lab will be of use in future designs utilizing oscillators, such as the Arduino pcb or brd3.

**Lab 14**

**Introduction:**

One thing to take into consideration while designing circuits is the possibility of electrostatic discharge events or ESD events. Sometimes charge accumulates on objects or people which will unwittingly pass this on into sensitive electronics. One way to combat this is to use a TVS diode array. In this lab, a TVS diode array IC is used to alter a 10v, 10khz sinewave, into a 5v 10khz trapezoidal wave. This demonstrates the ability to reduce incoming voltage spikes to an acceptable level.

**Circuit schematic:**

A diagram of a circuit board

Description automatically generated

**Circuit breakdown:**

The Zener diode in-between ground and ref has a breakdown voltage of 6v. This means that if the ref voltage exceeds 6 volts, the Zener diode shorts with ground and reduces the voltage in order to keep it at less than or equal to 6 volts. The unfiltered sinewave is connected to pins 1 and 3, and the oscilloscope is connected to pins 1 and ground in order to measure the resulting filtered waveform.

A diagram of a circuit

Description automatically generated

**Test apparatus:**

**A white electronic device with wires

Description automatically generated with medium confidence**

**Unfiltered waveform:**

**A screen shot of a computer

Description automatically generated**

**Filtered waveform:**

**A screen shot of a graph

Description automatically generatedc**

**Recorded data:**

**A white grid with black text

Description automatically generated**

**Applications:**

If the TVS chip is used to protect a USB connection from ESD events, the positive D+ should be connected to one of the terminals of the chip, for instance line 1, and the negative D- line should be connected to ground. The unfiltered waveform should be fed into lines 1 and 3, or lines 4 and 6. This should protect the connection from exceeding 6v.

**Conclusion:**

In this lab the importance of TVS chips were covered. TVS chips can be used to protect various electronics from ESD events, and are important in the use of a multitude of communication protocols such as USB connection.