# Main section for developing Background

{A}“The majority of clock sources for microcontrollers can be grouped into two types: those based on mechanical resonant devices, such as crystals and ceramic resonators, and those based on electrical phase-shift circuits such as RC (resistor, capacitor) oscillators.” [4] Crystal, ceramic resonator, and RC oscillators are all sensitive to electromagnetic interference; however, only the RC oscillator has the additional disadvantage of poor temperature performance. One of the few advantages of the low accuracy RC oscillator is that it is the lowest cost option available, and is also typically available onboard a microcontroller with no extra circuitry necessary. This makes RC oscillators the desired source for non-critical or “low-budget situations”. [11]

{B} Issues involving EMI effects on electrical systems have been known about for a long time. Documents addressing how to handle these issues often cite typical sources of where the EMI may be coming from. For example, in an application note on erratic behavior in power-driven wheelchair due to EMI, the document cites that “common sources of EMI [include] cellular phones, CB radios, TV and radio stations, amateur radios and fire and ambulance radios.” [14] This citation provides justification for the frequencies we will be testing including: 1 MHz (AM radio stations), 100 MHz (FM radio stations), 600 MHz (UHF TV), 850 MHz, (Cellular), and 1900 MHz (Cellular). The widespread presence of Wi-Fi signals at 2.4 GHz and 5 GHz in 2015 justifies its inclusion to the test frequencies.

{C} Methods for establishing temperature sensitivity on frequency for RC oscillators and mechanical oscillators are well established, and may provide insight on how to properly present data and errors after measurements have been taken. Since temperature variation in a crystal oscillator is small, “the frequency error of a crystal oscillator (denoted ε) is expressed in ppm (parts per million)”. [6] If the drift due to RF emissions is too much, the ppm method will become ineffective, and the drift will be presented as percent error.

{D} Solutions to measure to RC oscillator’s frequency include using a spectrum analyzer or a frequency counter. Using a spectrum analyzer involves connecting the analyzer’s 50 ohm input to an antenna port to measure the output frequency error on the RF carrier and hence, ε. For most chips with a clock-out function, using a frequency counter is the simplest solution. Frequency counters measure the frequency of a signal by counting how many times a signal passes past a threshold value. Selecting a longer time base interval allows for more samples to occur, which in turn results in a more accurate result. To ensure the accuracy of the instrument it must be brought up to operating temperature. This will require leaving the instrument on for sufficient time before measurements are taken. A frequency counter with a data port will be need for data collection, such as a RS232C port on the B&K Precision 1823A, 1856D frequency counter. [13]

{E} Despite the large amount of data available on temperature drift, there is no standard time to expose the devices to temperature that could be equated to the amount of time we should expose the devices to RF radiation. Therefore, it is reasonable that exposure should occur for an hour to account for the potential of long term effects. Frequency counter sweep time will be set at an interval of 1 second to capture short term drift effects. For an oscillator operating in MHz a sweep time of 1 second will ensure plenty of counter samples for accuracy of measurement, while still allowing for many data points (3600 for a hour of testing) to be collected over the testing period.

{F} RF test chambers are anechoic chambers and “are used today for performing EMC measurements,” and provides shielding from unwanted environmental EMI as well as highly reducing . [16] These chambers are typically rated for emissions in the frequency range of 30 MHz up to 40 GHz. [16] We will be testing frequencies as low as 1 MHz. “While, there are standard that call for radiated measurements down to the low kHz or even to the low Hz range, these standards do not specify any need for absorption or anechoic behavior”. [16] “In most cases, at these low frequencies where current absorber technology cannot deliver any level of absorption, the chambers are going to be too small (electrically) for resonant modes to appear.” [16]

{G} The basic equipment needed to produce RF emissions in the frequency range we need is a signal generator, a power amplifier, a transmission line, and a radial antenna. Signal generators are limited on frequency range and output power, so an RF power amplifier is needed to reach the desired power densities.

# Obsolete text

{C} This way, the ppm error will remain the same if the clock is being observed from the oscillator itself, or if the clock is being observed as the output of a frequency multiplier such as a PLL. Special caution will to taken when setting up the microcontroller that no clock tuning, clock divide down, or PLL functions are enabled that would introduce unwanted error. If these clock functions are unavoidable, the correct ideal frequency will be calculated and used in the calculation of the error in parts per million.

{D}Since the microcontroller clock signals will be in the MHz range, a time interval of 10 seconds (a typical option) may not be necessary. However, since we are exposing the microcontrollers to RF emissions for 1 hour, a long time interval will be used to increase accuracy.

# OUTLINE

**\*NOTE: this outline will be primarily used to expand ideas and topics in an organized manner. Any grey text, for reasons sometimes not specified, is obsolete or not applicable, but remains for documentation purposes.**

1. Frequencies in question (Where the RF radiation is coming from)
   1. Wifi
      1. 2.4 GHz
      2. 5 GHz
   2. Space
      1. Frequencies?
   3. Radio towers
      1. AM radio
         1. 535-1605 kHz [8]
         2. Carrier frequencies of 540 to 1600 kHz are assigned at 10 kHz intervals. [8]
      2. FM radio
         1. 88 to 108 MHz [8]
   4. Cellular towers
      1. 824-896 MHz commonly termed 800 MegaHertz (may also be known as 850MHz). [9]
      2. 1850MHz-1990MHz commonly termed 1900 MegaHertz or 1.9 GigaHertz. [9]
2. Power densities for each frequency
3. Clock sources and radiation
   1. Often in space applications, electronic equipment must be designed to withstand conditions not typically encountered on earth. For example, missions to Venus must face extreme “high temperature up to 460~470 degrees celsium, high pressure to 90 bar, shock and vibration, [as well as] total dosage exposure.” [7]
4. Clock sources
   1. Overview of operation
      1. Oscillator types
         1. Crystal oscillator
         2. Ceramic resonator
         3. Internal Fast RC oscillator
      2. Chip modes
         1. XT Mode, medium gain, medium frequency mode to work with crystal frequencies of 3.5MHz to 10MHz [1] pg21
         2. HS Mode, High Gain, High-Frequency mode used to work with crystal frequencies of 10 MHz to 40 MHz [1] pg21
         3. EC Mode, if the on-chip oscillator is not used, the EC mode allows the internal oscillator to be bypassed. [1] pg21
      3. Oscillator Start-up Time [1] pg22
         1. Primary oscillator
         2. In reference to the experiment, the oscillator should be stable when taking measurements, and the oscillator startup time should be avoided.
      4. RC oscillator
         1. 7.37 MHz
         2. -12% to +11.625% tunable
         3. Phase shift oscillator [2]
         4. Wein bridge oscillator [2]
         5. Op-amp oscillators are restricted to the lower end of the frequency spectrum because they do not have the required bandwidth to achieve low phase shift at high frequencies. [3]
         6. “RC oscillators, in contrast, provide fast startup and low cost, but generally suffer from poor accuracy over temperature and supply voltage, and show variations from 5% to 50% of nominal output frequency.”
         7. “internal RC oscillator (RCO) is useful in applications where an external quartz crystal or resonant element cannot be used for cost reasons.” [5]
   2. Purpose for each type of oscillator
      1. Crystal oscillators
         1. “Crystal and ceramic resonator-based oscillators (mechanical) typically provide very high initial accuracy and a moderately low temperature coefficient.” [4] If a system requires a very stable and accurate clock source, a crystal or ceramic oscillator is preferred. However, these clock sources incur an additional cost and take up board real estate
   3. Known data for internal oscillator

# Definitions

1. **Radiation** is the emission or transmission of energy in the form of waves or particles through space or through a material medium.
2. An **electronic oscillator** is an electronic circuit that produces a periodic, oscillating electronic signal, often a sine wave or a square wave.
3. **Total Effective Dose Equivalent (TEDE)** is the sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures). <http://www.nrc.gov/reading-rm/basic-ref/glossary/total-effective-dose-equivalent-tede.html>
   1. This definition may be equivalent to “Total dose exposure” in [7]

# References

* [1] <http://ww1.microchip.com/downloads/en/DeviceDoc/70005131a.pdf>
  + dsPIC33/PIC24 Family Reference Manual – Oscillator module
* [2] <http://www.daenotes.com/electronics/digital-electronics/rc-feedback-oscillators>
  + Types of oscillators
* [3] <http://www.ti.com/lit/an/sloa060/sloa060.pdf>
  + Op amp oscillator
* [4] <https://www.maximintegrated.com/en/app-notes/index.mvp/id/2154>
  + Microcontroller clock sources
  + Maxim Integrated Application Note 2154
* [5] <http://www.atmel.com/Images/article_ac9_atmegaxx8pa-15-rc-oscillator.pdf>
  + Shorthand section on temperature drift by Atmel
* [6] <http://www.semtech.com/images/datasheet/xo_precision_std.pdf>
  + Temperature drift of crystal oscillators
* [7] <http://solarsystem.nasa.gov/docs/7_7SARIRIVI.pdf>
  + NASA presentation slides on *Extreme Temperature/Radiation Tolerant Crystal Oscillator for High Reliability & Space Applications.*
* [8] <http://hyperphysics.phy-astr.gsu.edu/hbase/audio/radio.html>
  + Frequency bands for radio signals
* [9] <http://www.criterioncellular.com/tutorials/bandsandfrequencies.html>
  + Frequency bands for cellular signals
* [10] <http://www.mtt-serbia.org.rs/microwave_review/pdf/Vol16No1-04-URodhe.pdf>
  + Paper on how EMI influences crystal oscillators.
* [11] <http://www.digikey.com/en/articles/techzone/2014/oct/mems-oscillators-challenge-quartz-crystals-in-rf-applications>
  + MEMS Oscillators challenge quartz crystals in RF applications.
* [12] <http://www.radio-electronics.com/info/t_and_m/frequency_counter/how-to-use-using-frequency-counter.php>
  + Frequency counter operation.
* [13] <http://www.mouser.com/ds/2/43/1823A_datasheet-181239.pdf>
  + Example frequency counter
* [14] <http://www.ti.com/lit/an/snoa382/snoa382.pdf>
  + TI app note of common frequencies of EMI that hit electric wheel chairs.
* [15] <http://www.rohde-schwarz.us/en/product/dst200-productstartpage_63493-11087.html>
  + 700 MHz to 6 GHz test chamber
* [16] <http://www.ets-lindgren.com/pdf/item_mwvr_0510.pdf>
  + Choosing the right chamber for your test requirements
* [17] <https://www.dsinstruments.com/wp-content/uploads/2013/10/SG6000L_Data_Sht_rev1-04.pdf>
  + Signal generator

# Notes

* Combination of temperature drift and RF drift could cause a severe change in clock frequency, which could result in a controller collecting false data
  + For example, an MCU checking how much power is being delivered to a circuit too quickly, due to an increased clock speed, could result in a premature shutdown attempting to prevent damage to the powered circuit. Conversely, checking too slowly, due to a decreased clock speed, could result in too much power being delivered to the circuit, damaging it.
* Could a smart phone’s own radio emissions affect the phones processor detrimentally? This question may provide adequate justification for our investigation of radiation of clock sources. May provide insight as to the possibility of using an internal oscillator to reduce cost.
  + What kind of sources do smart phones use?
  + This may be more applicable to peripheral devices in the phone, as the main CPU probably is using a really good clock source.
    - Do I now need to research how a smartphone operates…? Sigh.

http://www.mtt-serbia.org.rs/microwave\_review/pdf/Vol16No1-04-URodhe.pdf