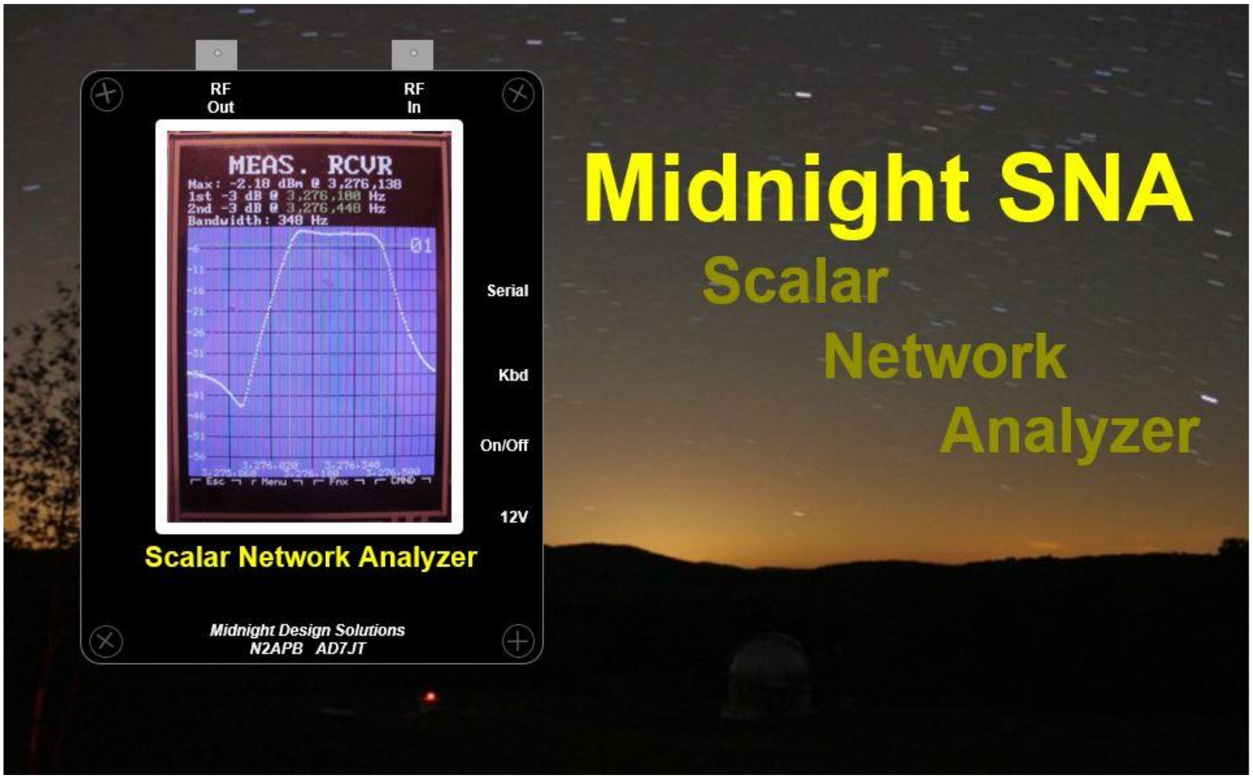

Tutorial 8 - Frequency Counter

for Firmware Version 4.30

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2016-02-29

This tutorial takes you through the steps to configure and use your MSNA to measure frequency. It includes a discussion of how frequency measurements are made, how to tune SNA timing functions for better accuracy, and a description of an RF signal conditioning circuit.

Contents

1. APPLIES TO

All Midnight SNA units running V4.30 firmware or later.

2. PREREQUESITES

The primary prerequisite for using the frequency counter is that the RF signal input (external interface connector, tip contact) must meet the voltage and timing requirements specified by Microchip for a 5V tolerant, 2x I/O pin. The basic requirements are as follows:

Voltage with respect to ground ....-0.3V to +5.6V
Maximum low level..0.66V
Minimum high level 2.31V

Low Frequency Counter (LFC):

Maximum frequency...11 MHz
Minimum High Time ....45 ns
Minimum Low Time ....45 ns

High Frequency Counter (HFC):

Maximum frequency...40 MHz
Minimum High Time ....20 ns
Minimum Low Time ....20 ns

The External Interface connector, sleeve contact can provide power with the following limits:

Maximum voltage 3.3V
Maximum current source..15 ma
Minimum output voltage sourcing ≤ 4 ma.............3.0V
Minimum output voltage sourcing ≤ 11 ma...........2.0V
Minimum output voltage sourcing ≤ 15 ma...........1.5V

3. ADDITIONAL REQUIREMENTS

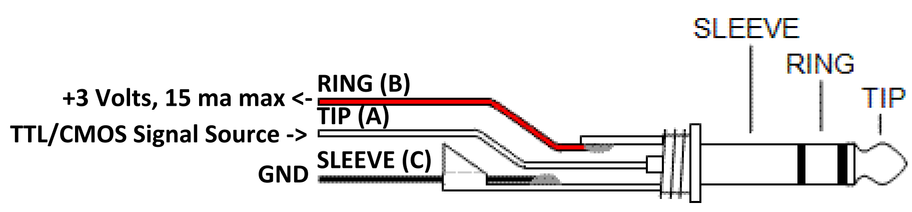
In addition to the MSNA, the following may be needed to complete this tutorial:

1. Adapters or cables to attach the signal source to the MSNA.
2. RF Conditioning circuit to assure meeting the interface electrical specifications.
3. Precision frequency source to fine tune the frequency counter calibration.

4. HOW IT'S DONE

The dsPIC33 microcontroller used in the MSNA has remappable peripherals that enable the firmware to assign many of the I/O pins to a number of peripherals. The MSNA External Interface (EI) pins are remappable. The EI function (and serial port baud rate) is selected using the **Configure Ext. Interface** [B] selection on the **Setup** menu. When a baud rate [1 - 9] is selected, the EI pins are assigned to a UART. When the **FREQ COUNTER** [F] is selected, the EI connector tip connection is assigned to a 32-bit counter and the ring connection to an I/O port pin.

Frequency Counter interface to External Interface Connector

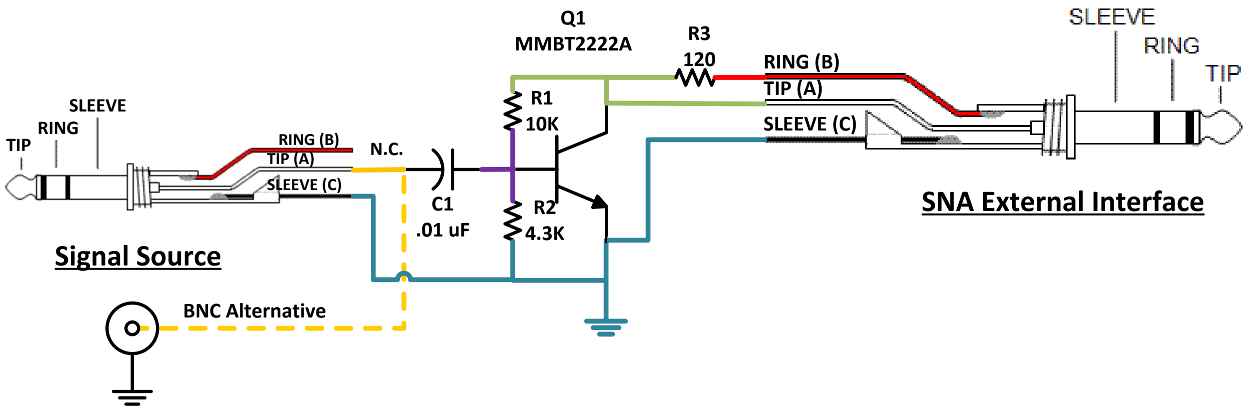


In Low Frequency Counter (LFC) mode, the counter is driven directly (1:1 prescaler) and in High Frequency Counter (HFC) mode, an 8:1 prescaler is used to reduce the input frequency by a factor of eight.

Another counter is used to generate a clock "tick" every second. At each tick of the clock, the firmware reads the current value of the 32-bit frequency counter and resets the counter to zero. In LFC mode the frequency count is used as-is, in HFC mode the frequency count is multiplied by eight to account for the 8:1 prescaler. The raw frequency count is smoothed some by computing a 10-point running average. The frequency (running average) is displayed on a version of the signal generator display and is updated every second. To speed up frequency acquisition after a significant change in frequency, tapping **Freq LO** [Home] will restart the running average with the next raw frequency count. To help indicate this condition, the current raw frequency count is also displayed.

The accuracy of the frequency meter is dependent on the accuracy of the one second timer which uses the system clock as a time base. The MSNA system clock runs at a nominal 40 MHz rate and is generated from an internal 7.37 MHz, RC oscillator driving a phase locked loop (PLL). The RC oscillator is factory-tuned and expected to remain within ± 2% of the tuned value over the specified temperature and voltage ranges for the controller. To improve on this, the system clock can be tuned by the firmware from -12% to +11.625% of the nominal frequency in steps of approximately 0.375% of the nominal clock frequency which corresponds to 37.5 KHz per step assuming a 10 MHz timing standard. Further improvement can be made by adjusting the frequency counting period (one second). The counting period can be increased or decreased by a maximum of 5 ms in steps ranging from 0.2 uS to 0.2 ms. The MSNA provides support for tweaking both of these values.

5. RF SIGNAL CONDITIONING CIRCUIT



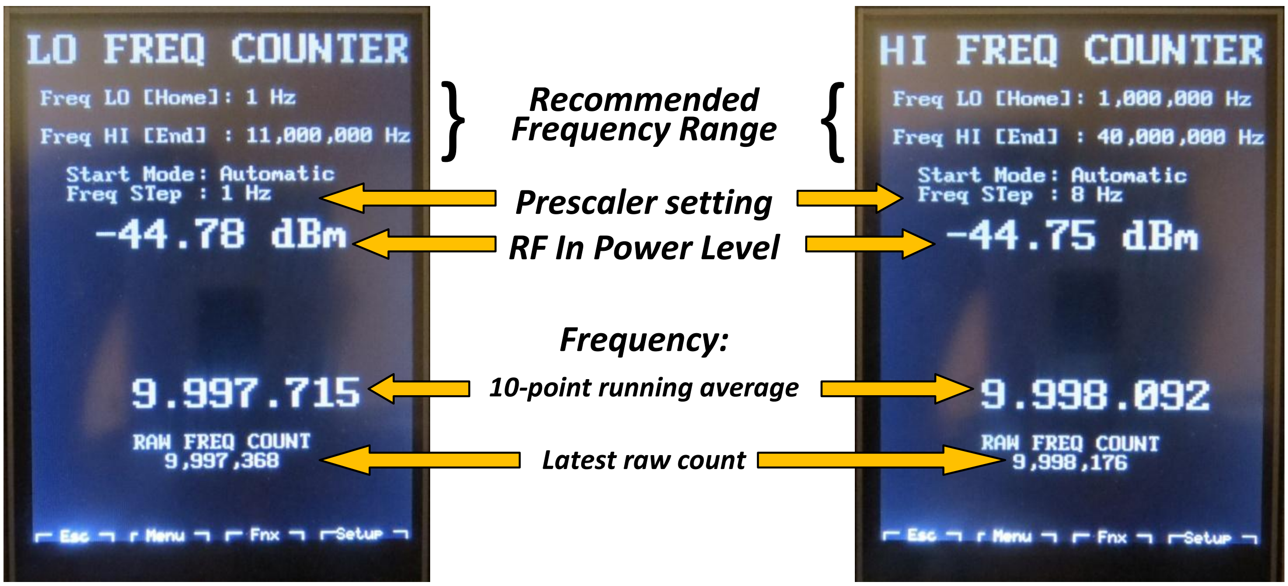
When the RF signal source satisfies the voltage levels specified above, it can be connected directly to the tip connection of the EI connector. When these specifications cannot be guaranteed, a conditioning circuit will be required. The circuit shown above will limit the voltage levels to within specification and provide some gain for weak input signal levels. The circuit is powered by the I/O pin connected to the sleeve connection which is held at a logic 1 or "high" logic level when the frequency counter input is specified for the EI.

I built my conditioning circuit using surface-mount devices on a piece of copper clad PCB material small enough to fit in the housing of a 3.5 mm stereo audio connector. Appendix A shows the details of this implementation.

6. MEASURING FREQUENCY

To activate the frequency counter do the following:

1. Select **FREQ COUNTER** [F] from the EI Configuration menu (**Setup** [Scroll Lock] > **Configure Ext. Interface** [B]) to configure the EI for frequency counter input.
2. Connect the signal source to the EI. Use an RF Conditioning circuit if required.
3. Start a macro with op modes set to **F** [F or 2] for HFC or **f** [f or 1] for HFC. If desired, enter a title on page one. Leave the rest of the form blank.
4. Tap **Start Mode** [A] to set to automatic.
5. Observe one of the following modified signal generator displays.



- Tap **Freq LO** [Home] to clear and restart the running average.
- Tap **Start Mode** [A] to toggle start mode between Automatic and Manual.
- Tap anywhere else [SPACE] to take one reading. (This is normally only useful in manual start mode.)

7. CALIBRATION

Due to the MSNA's lack of a precision time base it will be necessary to regularly calibrate the frequency meter. This will require an accurate signal source. I recommend 10 MHz as a convenient frequency standard since it can be used with both the HFC and LFC. This frequency is a very common standard and can easily be checked against WWV. The following assumes a 10 MHz frequency standard.

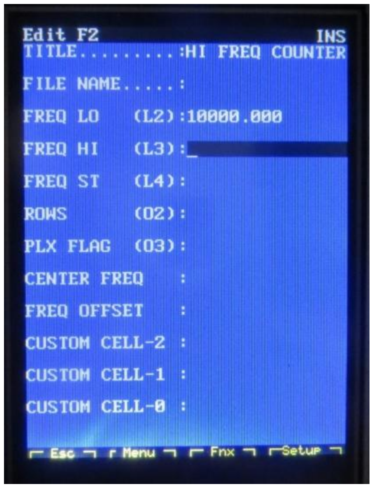
Here are some possible sources for an accurate signal source:

- A laboratory, calibrated signal generator such as an HP8640B often found listed on eBay.
- A GPS receiver with its PPS/TimePulse frequency set to 10 MHz. A u-blox GPS receiver can be setup using the MSNA running the GDT application.
- A second MSNA after setting its reference clock frequency with Tutorial 0 and the signal generator frequency to 10 MHz.
- The RF Out signal after setting its reference clock frequency with Tutorial 0.

There are two calibration modes for the frequency counters and they are the same for the LFC and HFC. A coarse calibration is done by adjusting the system clock frequency. A fine adjustment is done by adjusting the number of system clock cycles between frequency counter readings. The adjustment procedures can be performed with either the LFC or the HFC.

Using RF Out as a Calibration Signal

The DDS-60 is normally turned off when using the frequency counter. To use the **RF Out** signal, the DDS-60 must be turned on. The DDS-60 will be turned on if a value is entered in the FREQ LO line of the macro form. When the macro is started, the DDS-60 frequency will be set to FREQ LO and the Freq LO line on the display will be rendered in yellow to alert us the DDS-60 is on.



Coarse Adjustment - System Clock Frequency

With the frequency counter running, and our frequency standard input to the EI connector, tap **Tweak Sys Clk** [CTRL-T] to activate the system clock tweak function.

Use the **+** [UP ARROW] and **-** [DOWN ARROW] buttons to adjust the system clock period. Each time an adjustment is made, the frequency counter is cleared and the ten-point running average is restarted. The current adjustment to the system clock period is shown as a percent of the nominal clock period. The adjustment range is from -12% to +11.625% in increments of 0.375%. This means that with a 10 MHz frequency standard, each increment corresponds to about 37.5 KHz in the frequency reading. Tap **Save & End Tweak** [Enter] on the context menu to save the current setting to EEPROM and return to the normal frequency counter display Use this calibration first to get as close as possible then use the following adjustment to fine tune the frequency counter.

Fine Adjustment - Counting Period

With the frequency counter running, and our frequency standard input to the EI connector, tap **Tweak Period** [ALT-T] to activate the frequency counting period tweak function.

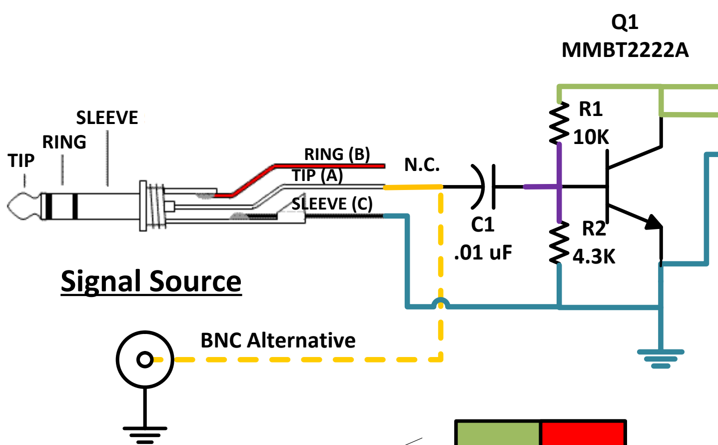
The current adjustment to the counting period is shown in microseconds. Each tap of the **+** [UP ARROW] and **-** [DOWN ARROW] will subtract or add 0.2 uS to the one-second counting period. With a keyboard attached, the Control [Ctrl] and Alternate [Alt] keys can be used in conjunction with the UP ARROW and DOWN ARROW keys to increase the increment/decrement as follows:

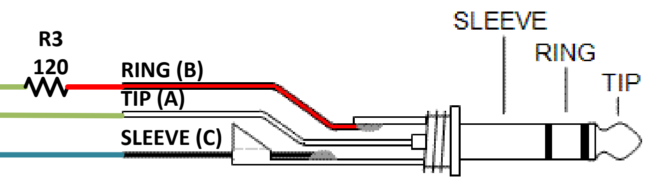
Ctrl/Alt	INC/DEC	STANDARD CYCLES*
none	0.2 uS	2 Hz
Alt	2.0 uS	20 Hz
Ctrl	20.0 uS	200 Hz
Ctrl+Alt	200.0 uS	0.2 KHz

* assumes a 10 MHz frequency standard.

Each time an adjustment is made, the frequency counter is cleared and the ten-point running average is restarted. The counting period can be adjusted up or down a maximum of 5 ms. Tap **Save & End Tweak** [Enter] on the context menu to save the current setting to EEPROM and return to the normal frequency counter display.

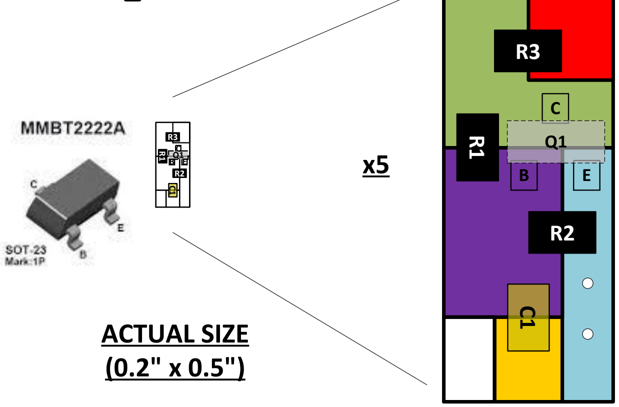
APPENDIX A. RF SIGNAL CONDITIONER





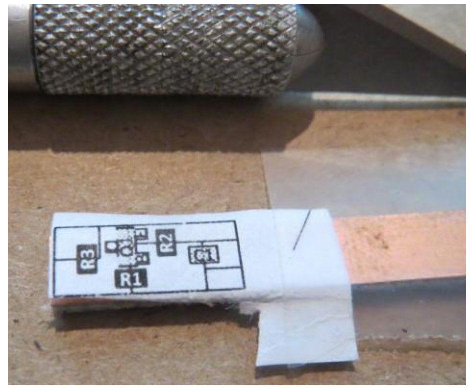
Signal Source

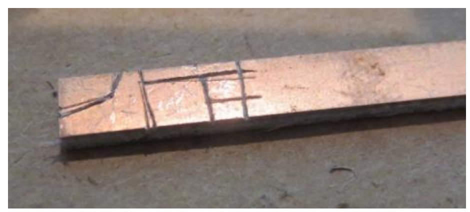
SNA External Interface

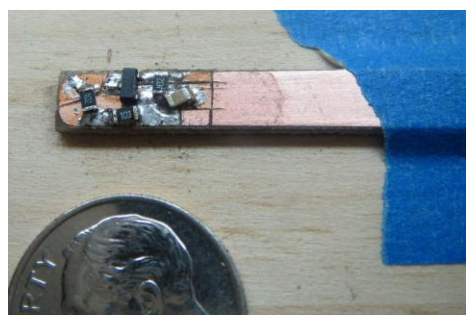


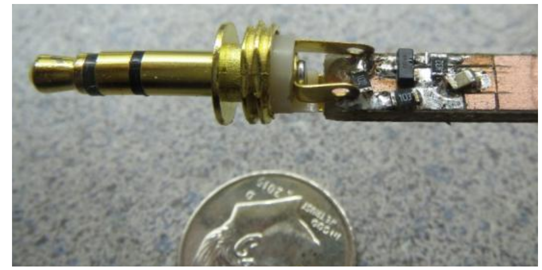
ACTUAL SIZE
(0.2" x 0.5")

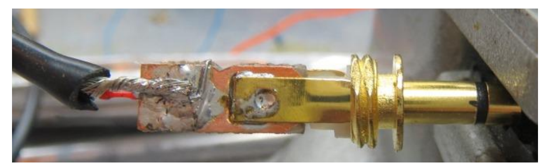
Backside solid
ground plane

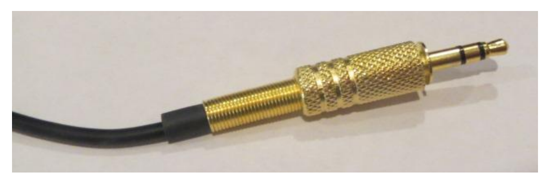












RF Signal Conditioner

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