Power Frequency Monitor Abstract

Entry # MT2227

Introduction

The Power Frequency Monitor (PFM) is a MicroChip dsPIC30F3012 micro controller based device used for high resolution measurement of AC power frequency. The Power Frequency Monitor communicates easily with a computer using a RS232 interface.

The Power Frequency Monitor is used to measure the frequency of the consumer power. The frequency range is between 30 to 80 Hz. In the USA, the power frequency standard is 60 Hz. In many other regions in the world, the power frequency standard is 50 Hz. Measuring this frequency accurately can provide an indicator of the relative stability of the local region's power grid compared to that of other non-synchronous regions.

PC software is used to download the data from the Power Frequency Monitor at a desired interval. The data can optionally be uploaded to a database and web server over the Internet to be displayed on a strip chart in a web browser with the data from other Power Frequency Monitors as illustrated by Figure 3.

The MicroChip dsPIC30F3012 micro controller was selected for its integrated input capture peripheral, UART (RS232), SPI (Serial Peripheral Interface), and integrated EEPROM features. The prototypes tested demonstrate that this micro controller has great reliability and performance. The dsPIC30F3012 has also proven to be durable enough to survive the abuse of my learning curve while I developed the prototypes!

System Description

Figure 1, below, is a block diagram of the Power Frequency Monitoring system. The system input is from any standard electrical outlet. Different AC-AC transformers may be used depending on the local electricity outlets and frequencies which vary depending on the country you are plugging into.

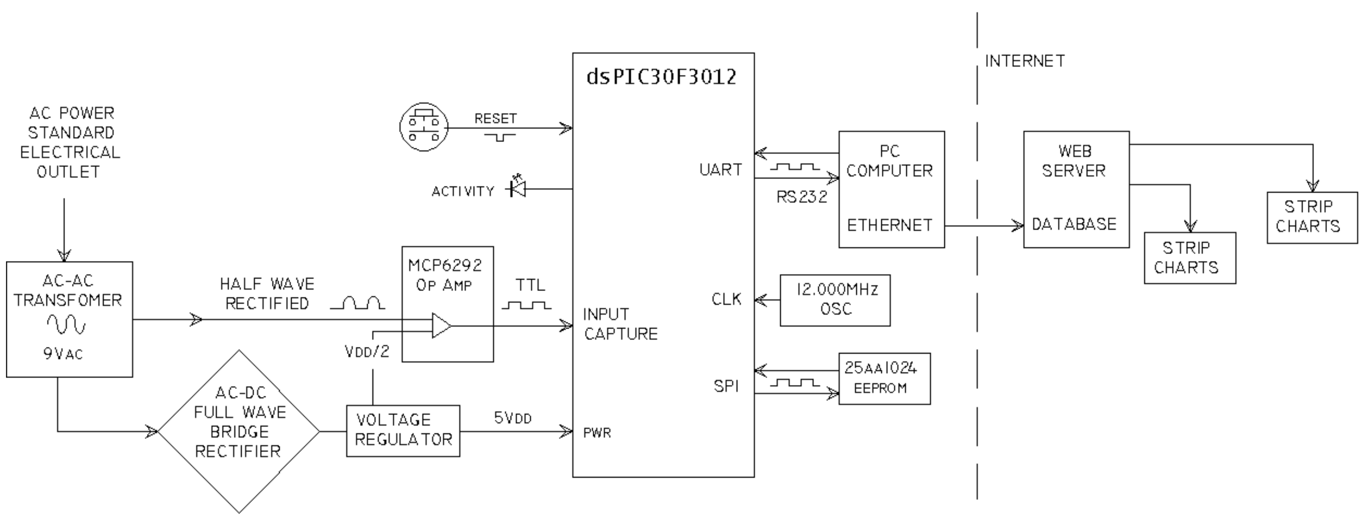


Figure 1 – System Block Diagram

The AC input is reduced to 9 VAC(rms) by small 120/9 V transformer. The 9 VAC from the transformer is connected to a full wave bridge rectifier and a half wave rectifier. The full wave rectified output is regulated to 5 VDC, used to power the system components, and used as a reference voltage for generating the frequency square wave.

The half wave rectifier output “pulses” are fed into an MCP6292 Operational Amplifier. The pulses are converted to a square wave by using the Op Amp as a voltage comparator. When the pulse voltage is less than Vref (about 3 VDC), the Op Amp's output is 0 V. When the pulse voltage is greater than Vref, the Op Amp's output is 5 V. The MCP6292 was selected because it provides a 10 MHz, high resolution, response. The Op Amp's output is connected to the Input Capture pin on the micro controller. Photo 1, below, shows the conversion of the half-wave rectifier signal to a square wave by the Op Amp.

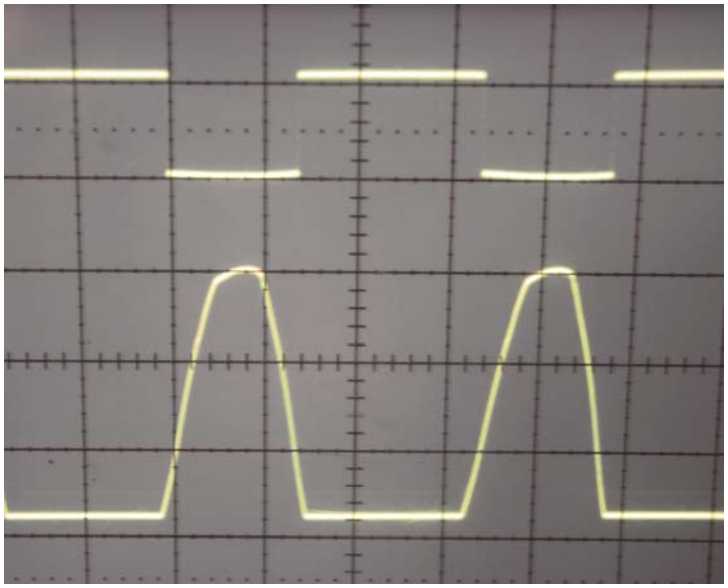


Photo 1 – Half Wave to Square Wave Conversion

The core component of the Power Frequency Monitor is the MicroChip dsPIC30F3012 micro controller. The micro controller uses an external 12.000 MHz clock crystal. The dsPIC30F3012 has an integrated Input Capture peripheral that is configured to generate an interrupt on the leading edge of the square wave signal pulses on the pin connected to the Op Amp's output.

The Input Capture peripheral counts the clock cycles between each leading edge and stores this data in a buffer. The clock cycles are divided by a prescaler of 8 so as not to overflow the 16 bit counter in the frequency range being measured. The following equations show that a prescaler of 8 provides a cycle count resolution allowing us to measure the desired frequencies without overflow.

(1sec / 60Hz) * (12,000,000 cycles/sec) / 8 = 25,000 cycles/Hz

(1sec / 50Hz) * (12,000,000 cycles/sec) / 8 = 30,000 cycles/Hz

The interrupt service routine (ISR) copies the buffered data to a memory variable so it can be accessed asynchronously by the program loop. The ISR then clears the buffer. The program loop determines what to do with the frequency data based on programmed rules and commands received from the PC. The data is typically transmitted to a PC via RS232 at the PC's request.

Optionally, the data can be stored in an external MicroChip 25xx1024 EEPROM for stand-alone data logging. Since data stream is continuous, stand-alone logging needs a rule set to determine what data is worth storing. Typically the data stored in the EEPROM is unusual samples like frequency spikes and dips. The EEPROM can be also be used to accumulate periodic runtime statistics.

A PC communicates with the dsPIC30F3012 using RS232. The PC software polls the micro controller periodically to get the frequency data. The data can easily be transmitted at speeds of 5 or more samples per second using ASCII and a moderate baud rate of 57,600 bps. Each data packet contains a sequence number and the data. The sequence number is used to determine if any packets were missed. Only a 3 wire connection is used and no handshake is performed.

The PC software is relatively simple. The software polls the Power Frequency Monitor at timer intervals and performs the frequency and deviation calculations on the data. It displays the data and can also upload the data to a database over the Internet using a web service. Figure 2, below, shows a screen shot of the PC software polling the micro controller every 200 ms and transmitting data to the database web server once per second.

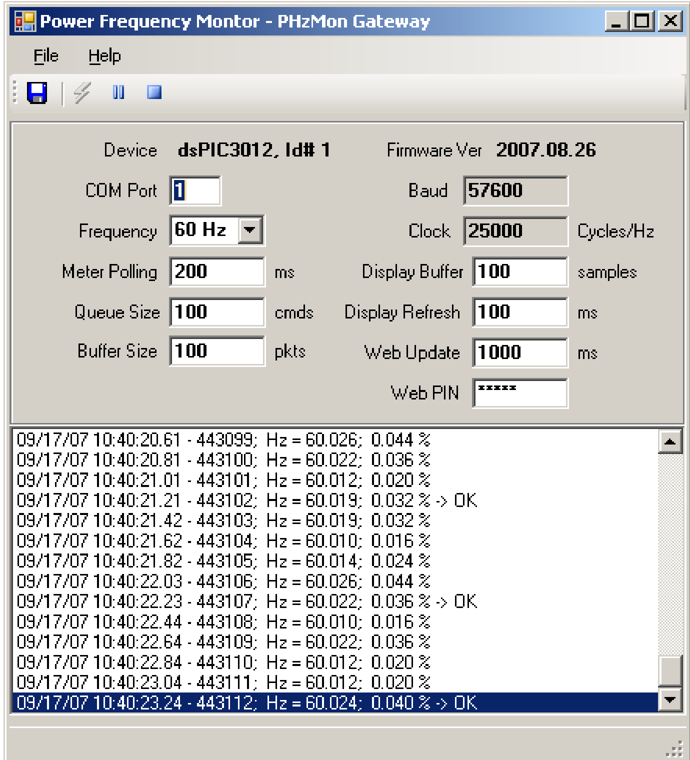


Figure 2 – PC Software Screen Shot

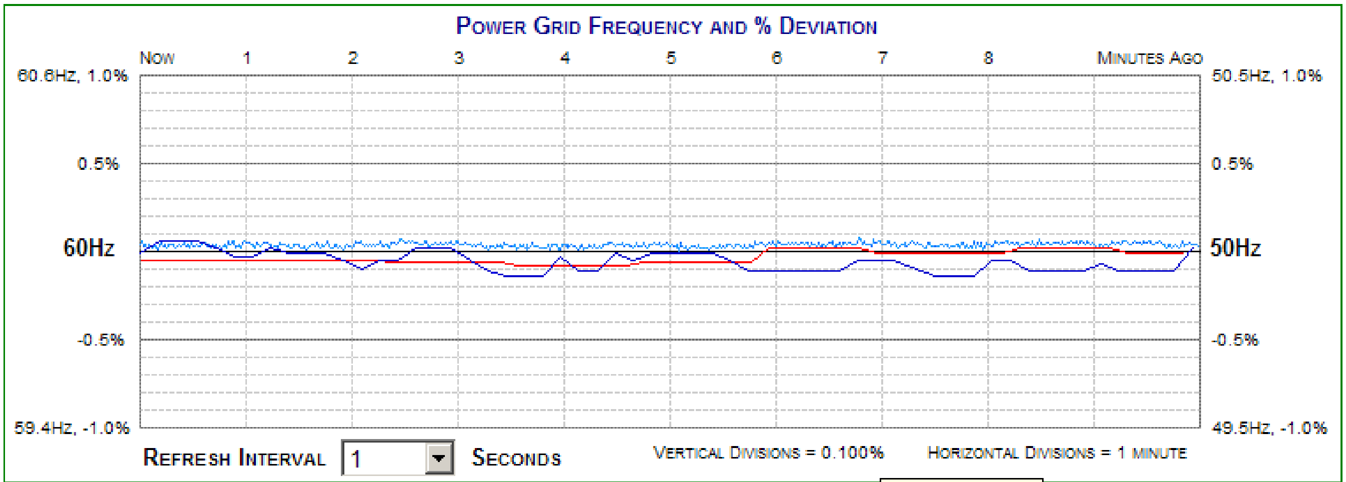
Application

The Power Frequency Monitor is used to monitor the frequency of electric power grids. By distributing the monitors over a wide regional or global area, the relative stability of the power grids can be observed and compared with each other. The Power Frequency Monitor developed here is a very inexpensive and simple way to observe frequency variations at various grid locations, for example, on either side of High Voltage DC transmission lines between grids to observe how well the connection endpoints are synchronized. Improving synchronization between grid nodes can decrease operating costs.

To make a relative comparison between grids of the two different frequencies, 50 Hz and 60 Hz, the following percent deviation calculation is used:

100 * [(Measured Hz) – (Rated Hz)] / (Rated Hz) = Deviation %

For example, the chart shown in Figure 3, below, shows the Houston Texas frequency (Rated = 60 Hz) compared to the North Island, New Zealand frequency (Rated = 50 Hz). The vertical deviation scaling is +/- 1.0%. The equivalent 60 Hz frequency scale is on the left and the equivalent 50 Hz frequency scale is on the right side of the chart.



Pick	Meter #	Hz Freq	% Dev	Last Reading	Grid Location
☑	1	60.022 Hz	0.036 %	09/17/07 11:05:14.66	Eastern USA, Severna Park, Maryland
☑	20	59.970 Hz	-0.050 %	09/17/07 11:05:13.80	Texas, Houston, TX, USA (10 seconds)
☑	90	49.990 Hz	-0.020 %	09/17/07 11:05:14.77	NZ-NI, North Island, NZ (sampled every 10 seconds)
☐	91	50.020 Hz	0.040 %	09/17/07 11:05:14.79	NZ-SI, South Island, NZ (sampled every 10 seconds)
☐	100	49.996 Hz	-0.008 %	09/17/07 11:05:14.63	UK, United Kingdom (off-line)

Figure 3 – Power Grid Frequency and % Deviation Chart

The PC software controls the resolution of the data displayed in the chart. If the Power Frequency Monitor, or "Meter", is on a high speed Internet or LAN connection with the server; the frequency can be sampled at a higher rate than meters with limited connectivity. The chart in Figure 3 shows Meter # 1 sampled at a rate of 1 sample per second, Meters #20 and #90 sampled at a rate of 1 sample each 10 seconds.

The PC software is also responsible for performing the frequency and deviation calculations. When the data is transmitted from the PC through the web service to the web server's database, the database assigns a time stamp to the data record. The web server is synchronized to a NIST time server. The actual original sample time will vary depending on latency in communication over the Internet; but samples are all time stamped to the standard NIST time at the time they are received; keeping the data lines on the chart relatively synchronized.

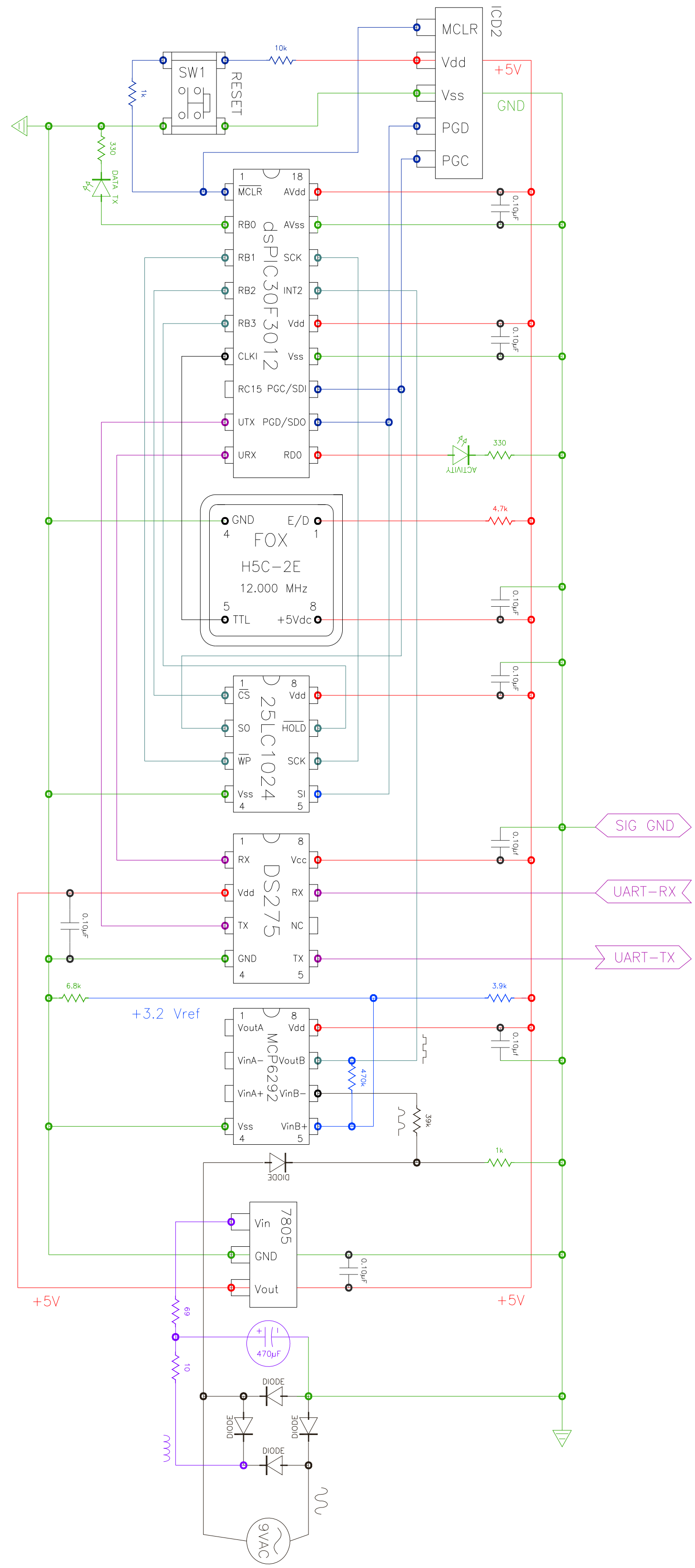


Figure 4 – Power Frequency Monitor Schematic

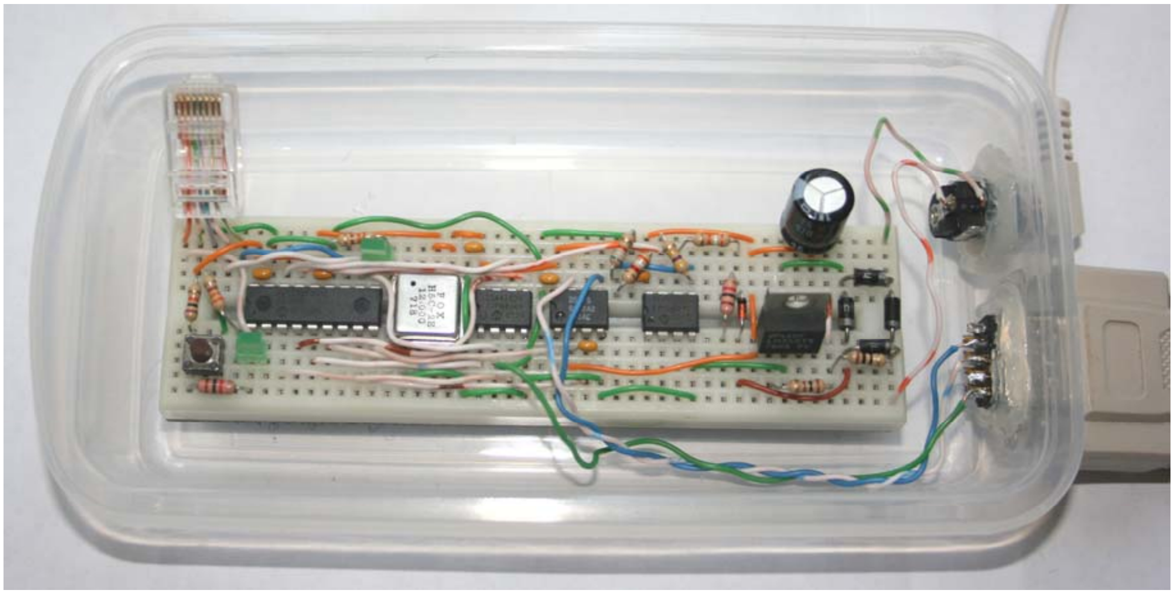


Photo 5 – Economical Packaging

Mom's favorite Tupperware worked best. Don't tell my mom!

Photo 6 – Completed Unit with Accessories

From left to right, top to bottom: RJ45 connector, In-Circuit Debugger (ICD2), 120/9VAC Transformer, Power Frequency Monitor, RS232 cable to PC (not shown).

Note: After the device is programmed, the ICD2 and connectors are no longer needed. The device is very power efficient and can be operated with the cover on without over heating.