AN521

Interfacing to AC Power Lines

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INTRODUCTION

This application note describes a simple method for measuring parameters from the AC power line. Parameters such as zero crossing, frequency, and relative phase can be measured. The method is useful for measurements on 50, 60, and 400 Hz power systems with voltages up to several hundred volts. The method requires only one external component, a resistor, and is more reliable than previously published methods using capacitors or bulky, expensive transformers.

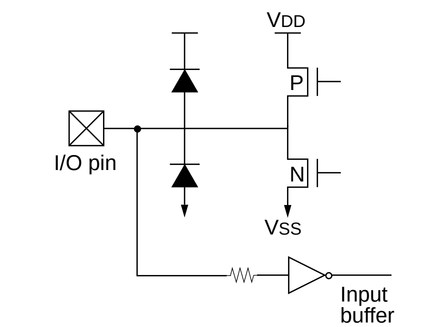
APPLICATIONS

This measurement method can be used in any application where power line parameters are used for system measurements or control. Typical applications are for switch timing (what part of the power cycle should the system be activated), power factor correction, power measurement, and power line monitor. An additional application is to generate timing or clock functions using the relatively stable power line frequency. The method is also useful for calibrating the oscillator frequency for accurate timing measurements when an inaccurate reference such as an RC oscillator is used to clock the PIC16C5X.

THEORY OF OPERATION

The application takes advantage of the input static protection circuitry that exists on all I/O pins of a CMOS PIC16C5X. These protection circuits are designed to short the inputs to the power supplies when a large overvoltage is applied, thus protecting the chip from static electricity spikes. On the PIC16C5X microcontrollers, this protection circuit is two large P-N diodes on each input (Figure 1). These diodes will short any voltage higher than V_{DD} to the V_{DD} supply and any voltage less than V_{SS} to the V_{SS} supply. They can take several milliamps of current without any damage to the chip. High voltages can be applied directly to the chip inputs as long as they are current limited.

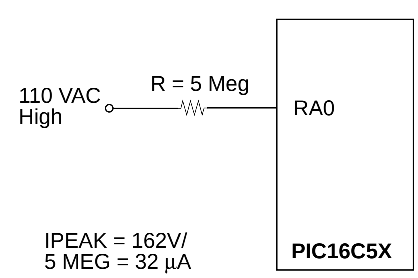
FIGURE 1: PIC16C5X SERIES INPUT PROTECTION CIRCUIT ON I/O PINS



Simplified structure of an I/O pin.

The least expensive method of current limiting is using a high value resistor. This method is shown schematically in Figure 2. The power line voltage is current limited by the resistor and then clamped by the input protection diodes internal to the PIC16C5X. A typical input waveform is shown in Figure 5. A 115V AC, 60 cycle sine wave will traverse from 0 to 2V in 32 µs so a typical threshold of 2V on the PIC16C5X I/O port will permit zero crossing detection accuracy of about 30 µs. If the typical capacitance on an I/O pin is 5 pF, then R should be (T = RC) 6MΩ or less for best zero crossing accuracy. A 5MΩ resistor with 115V AC applied to it will limit current to 32 µA, a value which is well within the safety margin of the PIC16C5X.

FIGURE 2: CURRENT LIMITING USING AN EXTERNAL RESISTOR

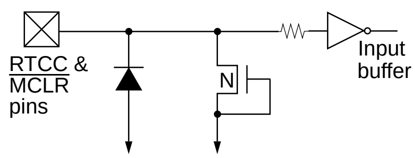


The user needs to be aware that the circuit required to connect the RTCC input to AC power line is slightly different. Each of the I/O pins has two diodes for input protection whereas RTCC pin has only one protection diode connecting to VSS (Figure 3). Therefore, it is necessary to connect a diode externally between RTCC pin and VDD in order to clamp the voltage on RTCC pin to VDD + 0.6V (approximately). See Figure 4. It is also recommended that resistor R be at least 2 MΩ.

RELIABILITY

Reliability of production devices that are directly connected to AC power is always a concern. Two failure modes are possible. First, the series resistor of Figure 1 might fail short, destroying the microcontroller.

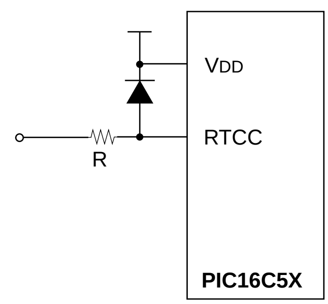
FIGURE 3: INPUT STRUCTURE AND RTCC PIN



Simplified structure of RTCC and $\overline{MCLR}$ pins. Grounded gate NMOS device provides ESD and overvoltage protection.

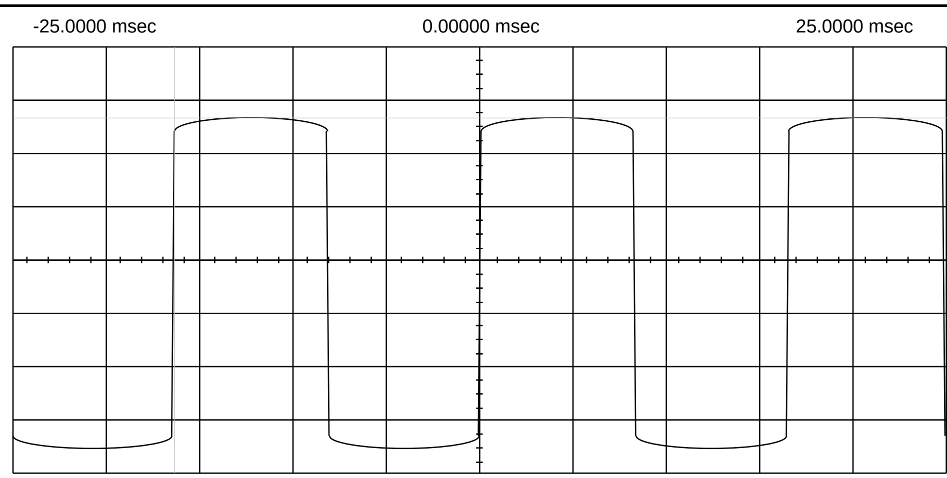
This is the most unlikely failure mode of a resistor, and resistors are more reliable than transformers or capacitors, which are the alternate components for measuring line parameters. This reliability can be enhanced even further by using two resistors in series. Both would have to fail short to cause catastrophic failure, a very unlikely event. The second possible failure mode is that excessive injection of current into the PIC16C5X input might cause the protection diode to open. This would allow the input to go to the power line peak voltage (162V) and short the input transistor gate oxide, causing device failure. The maximum continuous injection current into an I/O pin is specified ±500 µA.

FIGURE 4: CONNECTING AC POWER LINE TO RTCC PIN



Connecting to RTCC input. R ≥ 2 MΩ

FIGURE 5: INPUT WAVEFORM



Ch. 1 = 1.000 volts/div				Offset	= 3.000 volts
Timebase = 5.00 msec/div				Delay	= 0.00000 sec
Ch. 1 Parameters		Freq.	= 59.9797 Hz	Period	= 16.6723 msec
Rise Time	= 184.001 µsec	+ Width	= 8.26099 msec	- Width	= 8.41132 msec
Fall Time	= 174.005 µsec	Preshoot	= 0.000 volts	Overshoot	= 0.000 volts
P-P Volts	= 6.187 volts	RMS Volts	= 3.894 volts	Dutycycle	= 49.54 %

Waveform at part pin (RAO) •

R = 100K; Line: 60 Hz, 110V

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