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. This 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.

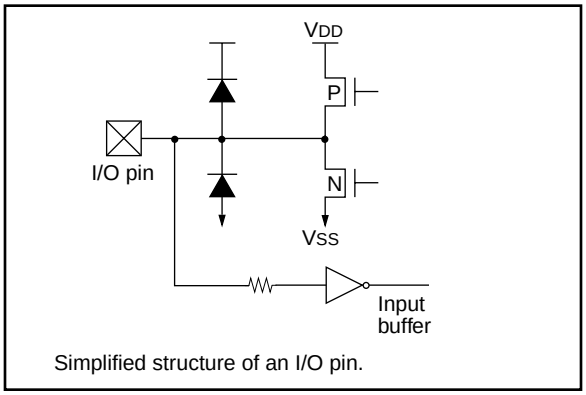
APPLICATIONS

This measurement method can be used in any application where power line parameters are used for system measurements or control. Typical applications are; 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. This method is also useful for calibrating oscillator frequency for accurate timing measurements when an inaccurate reference such as an RC oscillator is used to clock the PIC16C5X.

THEORY OF OPERATION

This 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 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.

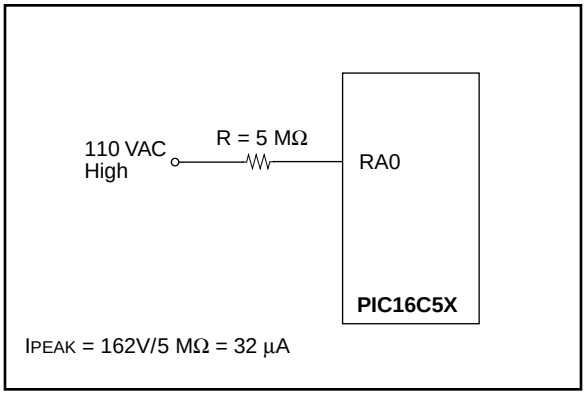
FIGURE 1: PIC16C5X SERIES INPUT PROTECTION CIRCUIT ON I/O PINS



Simplified structure of an I/O pin.

The least expensive method to limit current is to use a high value resistor. A block diagram is shown 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 115 VAC, 60 cycle sine wave will traverse from 0 to 2V in 32 μs, therefore a typical threshold of 2V on a 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) 6 MΩ or less for best zero crossing accuracy. A 5 MΩ resistor with 115 VAC applied to it will limit current to 32 μA, a value which is well within the safety margin of the PIC16C5X.

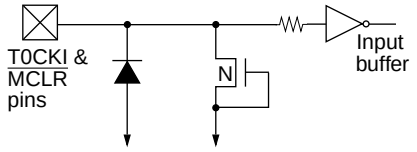
FIGURE 2: LIMITING CURRENT USING AN EXTERNAL RESISTOR



I_{PEAK} = 162V/5 MΩ = 32 μA

The user needs to be aware that the circuit required to connect the T0CKI input to an AC power line is slightly different than the other I/O pins. Each of the I/O pins has two diodes for input protection whereas the T0CKI pin has only one protection diode connected to Vss (Figure 3). Therefore, it is necessary to connect a diode externally between the T0CKI pin and V_{DD} in order to clamp the voltage on the T0CKI pin to V_{DD} + 0.6V (approximately). See Figure 4. It is also recommended that resistor R be at least 2 MΩ.

FIGURE 3: INPUT STRUCTURE OF $\overline{MCLR}$ AND T0CKI PINS



Simplified structure of T0CKI and $\overline{MCLR}$ pins. Grounded gate NMOS device provides ESD and overvoltage protection.

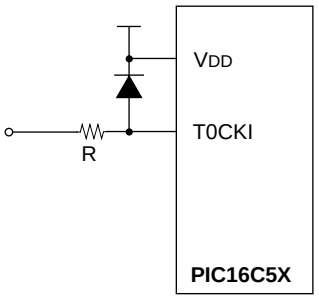
RELIABILITY

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.

A short is the most unlikely failure mode for 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.

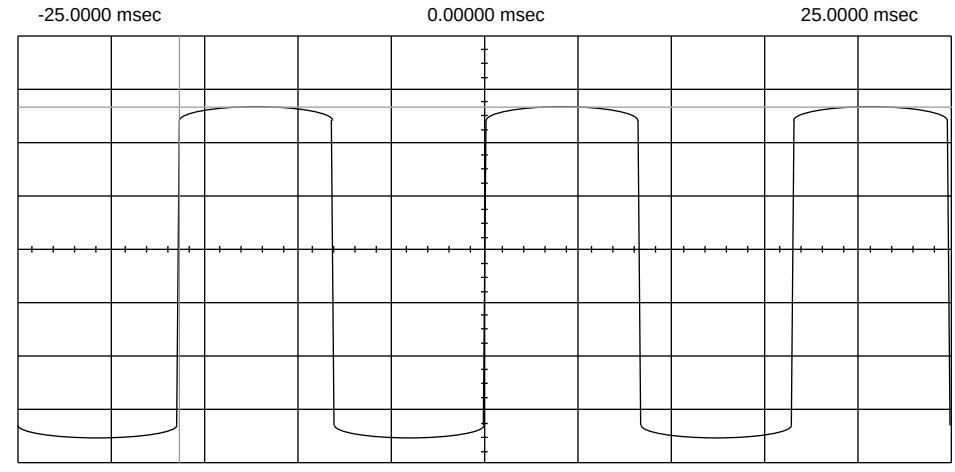
The second possible failure mode is that excessive injection of current into the PIC16C5X might cause the protection diode to open. This would allow the input to go to power line peak voltage (162V) and short the input transistor gate oxide, causing device failure. The maximum continuous injection current into an I/O pin is specified at ± 500 µA.

FIGURE 4: CONNECTING AN AC POWER LINE TO THE T0CKI PIN



Connecting to TMR0 input. R ≥ 2 MΩ

FIGURE 5: INPUT WAVEFORM



Waveform at part pin (RA0) •R = 100k; Line: 60 Hz, 110V

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