

## How to Implement ICSP™ Using PIC16F8X FLASH MCUs

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### INTRODUCTION

In-Circuit Serial Programming (ICSP™) with PICmicro™ FLASH microcontrollers (MCU) is not only a great way to reduce your inventory overhead and time-to-market for your product, but also to easily provide field upgrades of firmware. By assembling your product with a Microchip FLASH-based MCU, you can stock the shelf with one system. When an order has been placed, these units can be programmed with the latest revision of firmware, tested, and shipped in a very short time. This type of manufacturing system can also facilitate quick turnarounds on custom orders for your product. You don't have to worry about scrapped inventory because of the FLASH-based program memory. This gives you the advantage of upgrading the firmware at any time to fix those "features" that pop up from time to time.

### HOW DOES ICSP WORK?

Now that ICSP appeals to you, what steps do you take to implement it in your application? There are three main components of an ICSP system.

These are the: Application Circuit, Programmer and Programming Environment.

### Application Circuit

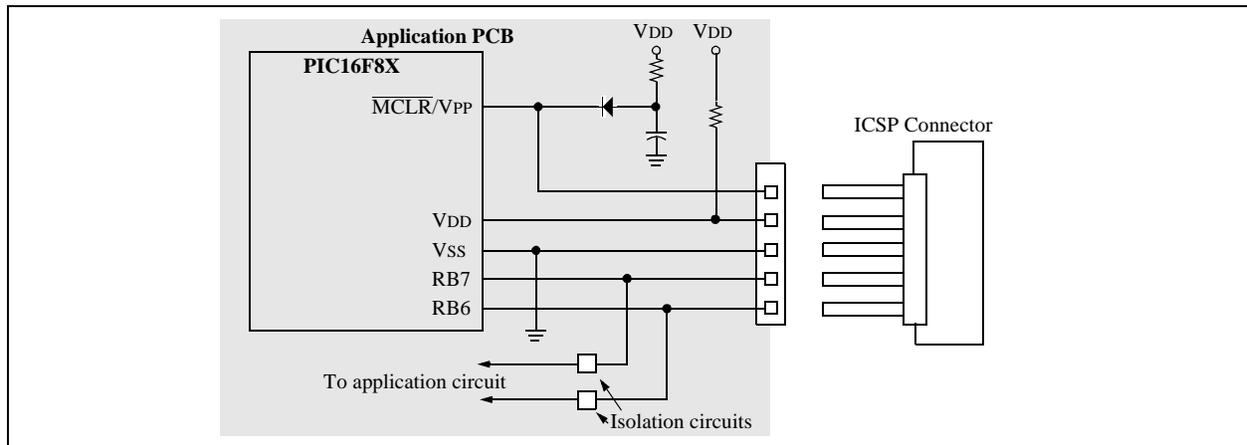
The application circuit must be designed to allow all the programming signals to be directly connected to the PICmicro. Figure 1 shows a typical circuit that is a starting point for when designing with ICSP. The application must compensate for the following issues:

1. Isolation of the  $\overline{\text{MCLR/VPP}}$  pin from the rest of the circuit.
2. Isolation of pins RB6 and RB7 from the rest of the circuit.
3. Capacitance on each of the  $V_{DD}$ ,  $\overline{\text{MCLR/VPP}}$ , RB6, and RB7 pins.
4. Minimum and maximum operating voltage for  $V_{DD}$ .
5. PICmicro Oscillator.
6. Interface to the programmer.

The  $\overline{\text{MCLR/VPP}}$  pin is normally connected to an RC circuit. The pull-up resistor is tied to  $V_{DD}$  and a capacitor is tied to ground. This circuit can affect the operation of ICSP depending on the size of the capacitor. It is, therefore, recommended that the circuit in Figure 1 be used when an RC is connected to  $\overline{\text{MCLR/VPP}}$ . The diode should be a Schottky-type device. Another issue with  $\overline{\text{MCLR/VPP}}$  is that when the PICmicro device is programmed, this pin is driven to approximately 13V

and also to ground. Therefore, the application circuit must be isolated from this voltage provided by the programmer.

**FIGURE 1: TYPICAL APPLICATION CIRCUIT**



Pins RB6 and RB7 are used by the PICmicro for serial programming. RB6 is the clock line and RB7 is the data line. RB6 is driven by the programmer. RB7 is a bi-directional pin that is driven by the programmer when programming, and driven by the PICmicro when verifying. These pins must be isolated from the rest of the application circuit so as not to affect the signals during programming. You must take into consideration the output impedance of the programmer when isolating RB6 and RB7 from the rest of the circuit. This isolation circuit must account for RB6 being an input on the PICmicro and for RB7 being bi-directional (can be driven by both the PICmicro and the programmer). For instance, PRO MATE® II has an output impedance of 1k $\Omega$ . If the design permits, these pins should not be used by the application. This is not the case with most applications so it is recommended that the designer evaluate whether these signals need to be buffered. As a designer, you must consider what type of circuitry is connected to RB6 and RB7 and then make a decision on how to isolate these pins. Figure 1 does not show any circuitry to isolate RB6 and RB7 on the application circuit because this is very application dependent.

The total capacitance on the programming pins affects the rise rates of these signals as they are driven out of the programmer. Typical circuits use several hundred microfarads of capacitance on VDD which helps to dampen noise and ripple. However, this capacitance requires a fairly strong driver in the programmer to meet the rise rate timings for VDD. Most programmers are designed to simply program the PICmicro itself and don't have strong enough drivers to power the application circuit. One solution is to use a driver board between the programmer and the application circuit. The driver board requires a separate power supply that is capable of driving the VPP and VDD pins with the correct rise rates and should also provide enough current to power the application circuit. RB6 and RB7 are not buffered on this schematic but may require buffering depending upon the application. A sample driver board schematic is shown in Appendix A.

**Note:** The driver board design MUST be tested in the user's application to determine the effects of the application circuit on the programming signals timing. Changes may be required if the application places a significant load on Vdd, Vpp, RB6 or RB7.

The Microchip programming specification states that the device should be programmed at 5V. Special considerations must be made if your application circuit operates at 3V only. These considerations may include totally isolating the PICmicro during programming. The other issue is that the device must be verified at the minimum and maximum voltages at which the application circuit will be operating. For instance, a battery

operated system may operate from three 1.5V cells giving an operating voltage range of 2.7V to 4.5V. The programmer must program the device at 5V and must verify the program memory contents at both 2.7V and 4.5V to ensure that proper programming margins have been achieved. This ensures the PICmicro option over the voltage range of the system.

This final issue deals with the oscillator circuit on the application board. The voltage on MCLR/VPP must rise to the specified program mode entry voltage before the device executes any code. The crystal modes available on the PICmicro are not affected by this issue because the Oscillator Start-up Timer waits for 1024 oscillations before any code is executed. However, RC oscillators do not require any startup time and, therefore, the Oscillator Startup Timer is not used. The programmer must drive MCLR/VPP to the program mode entry voltage before the RC oscillator toggles four times. If the RC oscillator toggles four or more times, the program counter will be incremented to some value X. Now when the device enters programming mode, the program counter will not be zero and the programmer will start programming your code at an offset of X. There are several alternatives that can compensate for a slow rise rate on MCLR/VPP. The first method would be to not populate the R, program the device, and then insert the R. The other method would be to have the programming interface drive the OSC1 pin of the PICmicro to ground while programming. This will prevent any oscillations from occurring during programming.

Now all that is left is how to connect the application circuit to the programmer. This depends a lot on the programming environment and will be discussed in that section.

## Programmer

The second consideration is the programmer. PIC16F8X MCUs only use serial programming and therefore all programmers supporting these devices will support ICSP. One issue with the programmer is the drive capability. As discussed before, it must be able to provide the specified rise rates on the ICSP signals and also provide enough current to power the application circuit. Appendix A shows an example driver board. This driver schematic does not show any buffer circuitry for RB6 and RB7. It is recommended that an evaluation be performed to determine if buffering is required. Another issue with the programmer is what VDD levels are used to verify the memory contents of the PICmicro. For instance, the PRO MATE II verifies program memory at the minimum and maximum VDD levels for the specified device and is therefore considered a production quality programmer. On the other hand, the PICSTART® Plus only verifies at 5V and is for prototyping use only. The Microchip programming specifications state that the program memory contents should be verified at both the minimum and maximum VDD levels that the application circuit will be operating. This implies that the application circuit must be able to handle the varying VDD voltages.

There are also several third party programmers that are available. You should select a programmer based on the features it has and how it fits into your programming environment. The *Microchip Development Systems Ordering Guide* (DS30177) provides detailed information on all our development tools. The *Microchip Third Party Guide* (DS00104) provides information on all of our third party tool developers. Please consult these two references when selecting a programmer. Many options exist including serial or parallel PC host connection, stand-alone operation, and single or gang programmers. Some of the third party developers include Advanced Transdata Corporation, BP Microsystems, Data I/O, Emulation Technology and Logical Devices.

## Programming Environment

The programming environment will affect the type of programmer used, the programmer cable length, and the application circuit interface. Some programmers are well suited for a manual assembly line while others are desirable for an automated assembly line. You may want to choose a gang programmer to program multiple systems at a time.

The physical distance between the programmer and the application circuit affects the load capacitance on each of the programming signals. This will directly affect the drive strength needed to provide the correct signal rise rates and current. This programming cable must also be as short as possible and properly terminated and shielded or the programming signals may be corrupted by ringing or noise.

Finally, the application circuit interface to the programmer depends on the size constraints of the application circuit itself and the assembly line. A simple header can be used to interface the application circuit to the programmer. This might be more desirable for a manual assembly line where a technician plugs the programmer cable into the board. A different method is the use of spring loaded test pins (commonly referred to as pogo pins). The application circuit has pads on the board for each of the programming signals. Then there is a fixture that has pogo pins in the same configuration as the pads on the board. The application circuit or fixture is moved into position such that the pogo pins come into contact with the board. This method might be more suitable for an automated assembly line.

After taking into consideration the issues with the application circuit, the programmer, and the programming environment, anyone can build a high quality, reliable manufacturing line based on ICSP.

## Other Benefits

ICSP provides other benefits, such as calibration and serialization. If program memory permits, it would be cheaper and more reliable to store calibration constants in program memory instead of using an external serial EEPROM. For example, your system has a thermistor which can vary from one system to another. Storing some calibration information in a table format allows the microcontroller to compensate in software for external component tolerances. System cost can be reduced without affecting the required performance of the system by using software calibration techniques. But how does this relate to ICSP? The PICmicro has already been programmed with firmware that performs a calibration cycle. The calibration data is transferred to a calibration fixture. When all calibration data has been transferred, the fixture places the PICmicro in programming mode and programs the PICmicro with the calibration data. Application note *AN656, In-Circuit Serial Programming of Calibration Parameters Using a PICmicro Microcontroller*, shows exactly how to implement this type of calibration data programming.

The other benefit of ICSP is serialization. Each individual system can be programmed with a unique or random serial number. One such application of a unique serial number would be for security systems. A typical system might use DIP switches to set the serial number. Instead, this number can be burned into program memory thus reducing the overall system cost and lowering the risk of tampering.

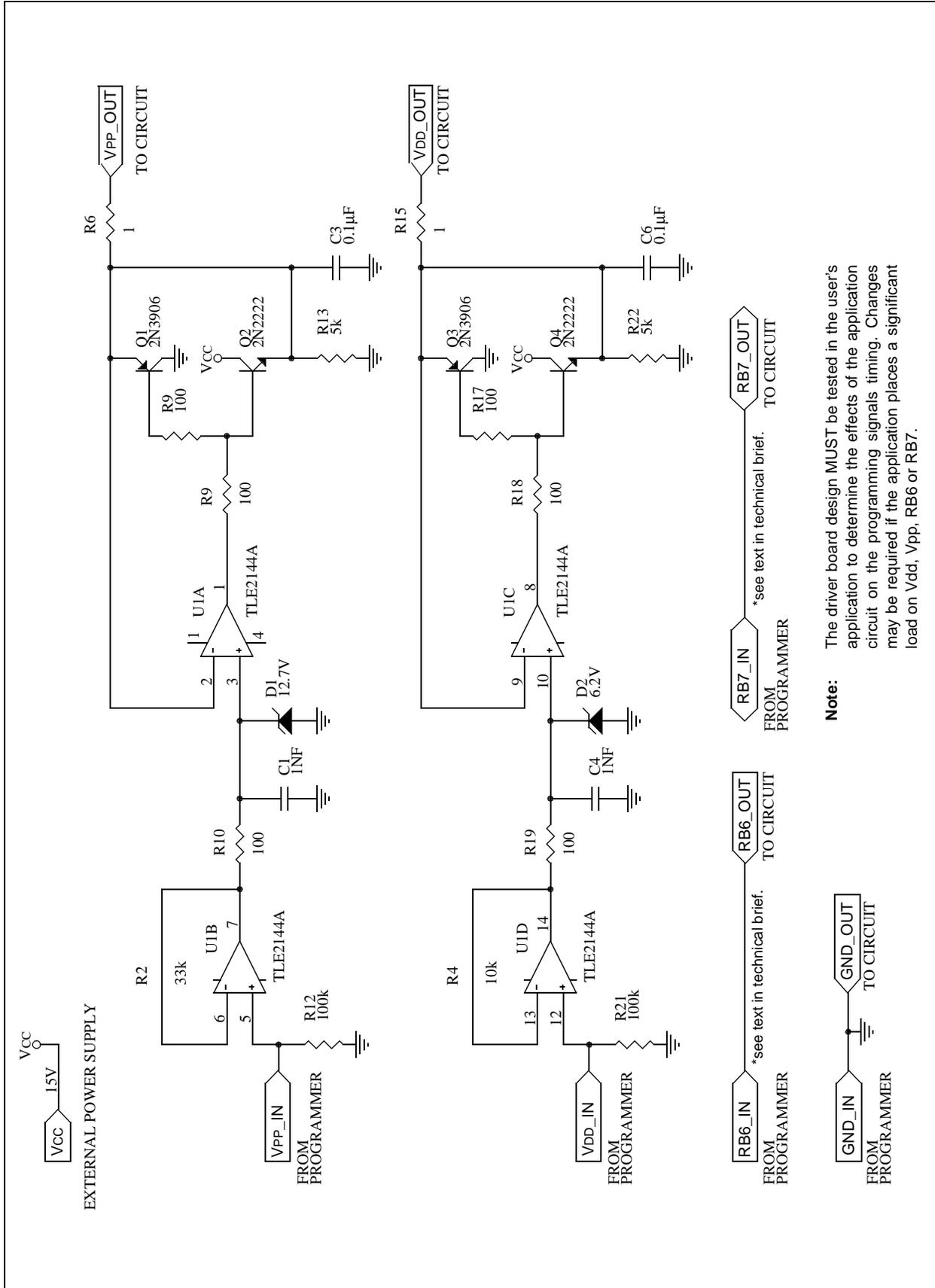
## Field Programming of FLASH PICmicros

With the ISP interface circuitry already in place, these FLASH-based PICmicros can be easily reprogrammed in the field. These FLASH devices allow you to reprogram them even if they are code protected. A portable ISP programming station might consist of a laptop computer and programmer. The technician plugs the ISP interface cable into the application circuit and downloads the new firmware into the PICmicro. The next thing you know the system is up and running without those annoying "bugs". Another instance would be that you want to add an additional feature to your system. All of your current inventory can be converted to the new firmware and field upgrades can be performed to bring your installed base of systems up to the latest revision of firmware.

## CONCLUSION

Microchip Technology Inc. is committed to supporting your ICSP needs by providing you with our many years of experience and expertise in developing ICSP solutions. Anyone can create a reliable ICSP programming station by coupling our background with some forethought to the circuit design and programmer selection issues previously mentioned. Your local Microchip representative is available to answer any questions you have about the requirements for ICSP.

## APPENDIX A: SAMPLE DRIVER BOARD SCHEMATIC



# How to Implement ICSP™ Using PIC16F8X FLASH MCUs

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