AN820

System Supervisors in ICSP™ Architectures

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INTRODUCTION

Semiconductor manufacturers have designed several types of circuit supervisors with varying types of functionality over the past few years. Some supervisors incorporate watchdog features as well as complex functions, such as programmable threshold levels. As it turns out, most system supervisor data sheets address typical supervisor functions related to Power-on Reset, power-down, and brown-out conditions. In order to serve a wide customer base, semiconductor manufacturers should also address system supervisors designed into systems where microcontrollers (MCUs) and programmable logic devices (PLDs) are programmed in-circuit. Programming PICmicro® microcontrollers in this fashion is known as In-Circuit Serial Programming™ (ICSP™), which can be implemented for a variety of reasons, including field upgrades.

System supervisors are available with several types of output stages. Some have active low output stages, some active high, and there are others similar to the MCP100, with output stages that drive RESET lines both high and low. Supervisor output stages are extremely important to understand for ICSP circuitry, since programming equipment actually drives the output stages when the MCU or PLD is being programmed. While there is a wide variety of supervisor types available on the market, this Application Note primarily focuses on the MCP120, which has an open drain, active low, output stage. Even though the MCP120 was chosen for this ICSP example, the design techniques included below are intended to guide designers with supervisors of all kinds for ICSP circuitry.

CIRCUITRY BACKGROUND

MCP120 Output Stage

A simplified schematic for the MCP120 output stage is shown in Figure 1. Nominally, the output stage of the MCP120 can handle sinking less than 1 mA of current in a high impedance state. That is, when the output is not driving low and when a voltage is applied to the output that is higher than the power supply level, the output can handle sinking less than 1 mA. Other pertinent electrical specifications for the device are shown in the data sheet, which includes test conditions for the chip.

The MCP120 has an open drain output, though it is not a true open drain. Specifically, the PMOS transistor on the high side of the output stage is diode-connected, as shown in Figure 1. When the voltage applied to the output of the supervisor exceeds the power supply for the chip, the PMOS transistor acts like a forward biased diode. Lastly, since the output stage is open drain, a pull-up resistor is required between the supervisor output and V_{DD}.

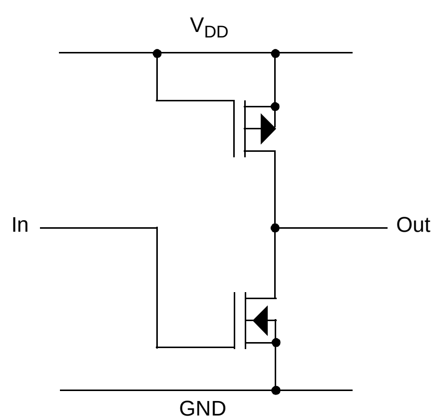

FIGURE 1: *MCP120 output stage simplified.*

ICSP Circuit Configuration

A schematic showing ICSP circuitry with the MCP120 is shown in Figure 2. A current limiting resistor, R_{CL}, limits the current driven into the output stage of the supervisor when the programming voltage is applied to the MCU. A pull-up resistor, R_{PU}, is placed between the supervisor output and V_{DD}, since the MCP120 output is open drain and active low. Calculations for the resistors are explained in the Design Methodology section.

The pull-down resistor, R_{PD}, shown in Figure 2 is useful during power-up and power-down sequences. Supervisor functionality is not specified at power supply voltages typically lower than 1 Volt, so the output stage of the supervisor could be in a high impedance state. If the supervisor output is high impedance and voltage is applied to the MCU from an external source, the processor could potentially run its program until the supervisor takes over and resets the MCU again. This is especially important in systems where multiple printed circuit boards are interfaced together and a secondary board might end up driving the MCU I/O pins before power is applied to the primary board.

Since the voltage on the $\overline{\text{MCLR}}$ pin on a PICmicro® MCU is very close to the power supply level, R_{PD} can be fairly large to minimize current consumption when the circuit is normally operating. Furthermore, during program and verify sequences, up to 13.25 Volts are applied to the pull-down resistor. Because of this, R_{PD} should also be large enough to minimize current consumption for the programming voltage supply. A value of 100 kΩ (+/-5%) results in a maximum of 140 µA when V_{PP} is applied to the microcontroller, or 134 µA if 1% resistors are used, which is a small load for most programmers. For battery powered applications, substantially larger valued resistors may be desirable for this purpose.

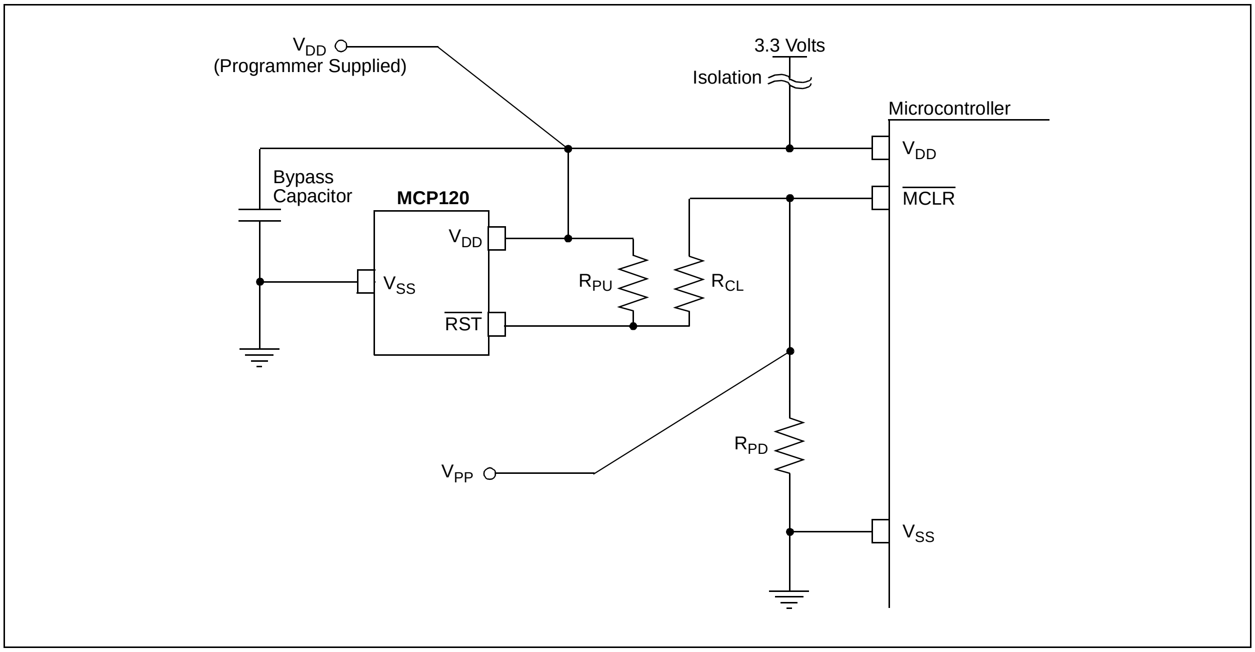

FIGURE 2: *Active low open drain ICSP circuit.*

Key Programmer Specifications

The PRO MATE® II and the ICSP Socket Module, part number AC004004, were used to test the circuit shown in Figure 2. Current drive for the programming voltage signal and current drive for the power supply signals are critical specifications for the ICSP socket module. For the V_{PP} signal, the output of the ICSP module can provide as much as 100 mA, and for the power supply signal, the ICSP socket module can drive as much as 400 mA. Furthermore, the PRO MATE II programs MCUs only at 5 Volts. However, it does have the capability to verify the memory contents of microcontrollers at power supply levels ranging from 2.5 Volts to 5.5 Volts.

Another important aspect to consider for In-Circuit Serial Programming includes the cable length for the interface. Not only are sufficient current drive capabilities required, but if a lengthy cable is used, reflections and oscillations may cause programming errors. Because of this phenomenon, manufacturers implementing ICSP architectures should keep their cables as short as possible. The circuits tested for the purpose of this article implemented the ICSP cable that is normally shipped with the ICSP module, which is about 6 feet long. Lastly, the end of the cable connected to the printed circuit board was modified to interface to a modular connector.

DESIGN METHODOLOGY

Absolute Maximum Clarifications

A critical question about designing this type of circuit revolves around the worst case voltages and currents applied to the circuit. Additionally, a circuit designer needs to determine whether or not the absolute maximum ratings for any of the components on the board are being exceeded. Knowing the largest voltage drops across the circuit enables a designer to calculate the resistor sizes so that absolute maximum ratings for all components are not exceeded. From the PIC16LF872 data sheet (DS30221), the maximum voltage that can be applied to the $\overline{MCLR}$ pin of the microcontroller cannot exceed 13.25 Volts. Additionally, the maximum voltage that can be applied to any pin on the MCP120, with respect to V_{SS}, is from -0.6 Volts to (V_{DD} + 1.0) Volts.

Calculations

Since the lowest voltage applied to V_{DD} is 0 Volts during programming, the voltage applied to the $\overline{RST}$ pin should not exceed 1.0 Volt. Knowing this, the circuit can be designed to limit the voltage applied to $\overline{RST}$ to a nominal 700 mV. This means that R_{CL} has to drop at most 12.55 Volts. If the assumption is made that all of the current flowing through R_{CL} is also flowing through R_{PU} when the supervisor output is high impedance, then R_{PU} needs to be 700Ω and R_{CL} should be at least 12.55kΩ. For standard 1% tolerance resistors, 715Ω and 12.7kΩ would be the correct selections for R_{PU} and R_{CL}, respectively. If standard 5% resistors are being used in the circuit, then 750Ω and 13 kΩ are the correct solutions.

In order to determine if this combination of resistors will work in the design, all of the permutations for power supply levels and output drive levels for the supervisor must include calculations for minimum and maximum currents and voltages in the circuit. While the microcontroller is being programmed, power supply levels can be as high as 5.5 Volts for the PIC16LF872 during verify operations. This can be further clarified by reviewing Figure 3. With this in mind, minimum and maximum circuit calculations show that this selection of resistors will work within tolerance.

Results

Figure 3 shows a successful programming waveform for two key nodes in an ICSP circuit. Channel 1 measured the voltage levels on the supervisor output pin, $\overline{RST}$, and Channel 2 measured the voltage applied to the node between the power supply pins of the microcontroller and the supervisor. The circuit schematic for this system was shown in Figure 2. Notice that Channel 2 in Figure 3 shows the verification voltage levels at 5.5 Volts and 2.5 Volts. Notice also that Channel 1 shows the voltage on the $\overline{RST}$ pin at about 700 mV when the supervisor output is driving low. Lastly, when the supervisor output is high impedance, Channel 1 shows a voltage level of 5.7 Volts applied to $\overline{RST}$, which is about 700 mV above the power supply.

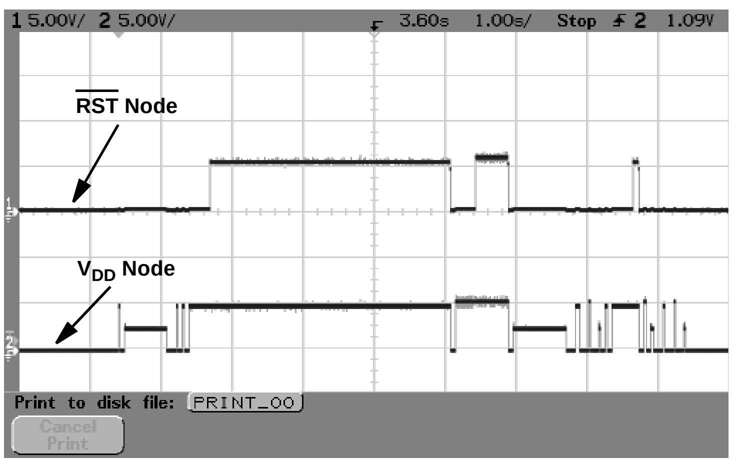

FIGURE 3: *Successful programming waveform.*

SUPERVISORS WITH PUSH-PULL OUTPUT STAGES

Typical N-Well CMOS Process

Figure 4 shows a cutaway view of a typical N-Well CMOS process, including connections for the MCP100 output stage. This type of process is currently used by Microchip Technology. When the node between the two transistors is raised above V_{DD}, the PMOS transistor allows current to flow from V_{PP} to the power supply. Because of this, ICSP circuits are difficult to implement with supervisors containing push-pull output stages.

Driving too much current into the supervisor output results in unstable operation, like the waveforms shown in Figure 5. This waveform was measured on a circuit using the MCP100 and the PIC16LF872. The circuit architecture was similar to the one shown in Figure 2, with the exception that the pull-up resistor was removed, since the MCP100 has the capability to drive the RESET pin both high and low. Also, the current limiting resistor was reduced to about 1 kΩ for this demonstration.

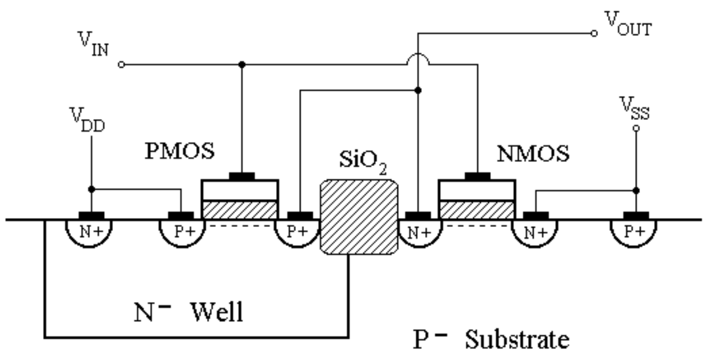

FIGURE 4: Push-Pull output in N-Well CMOS process.

Results

As shown in Figure 5, an excessive amount of current driven into the supervisor results in failed programming. In this case, the chip failed during the verification tests. It should be further noted that increasing the current limiting resistor yielded successful programming operations periodically. Because of the results of these tests, Microchip Technology recommends designing open drain supervisors into ICSP circuitry, rather than push-pull supervisors.

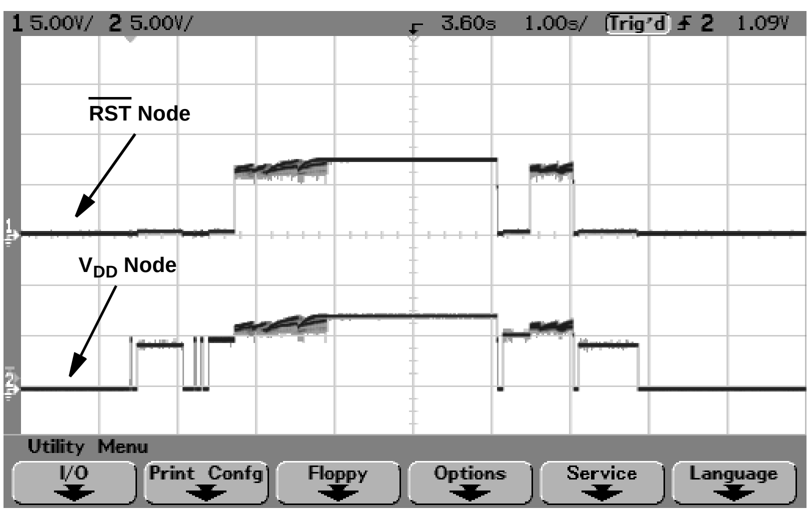

FIGURE 5: Failed verify programming waveform.

CONCLUSION

In summary, throughout this Application Note, output stages for system supervisors in ICSP circuits were discussed. The importance of understanding output stage architectures and how they interact with programming hardware was emphasized. Lastly, two ICSP circuits were included as examples. One circuit illustrated how to implement an ICSP interface between a microcontroller and a system supervisor, and the other demonstrated some of the pitfalls designers encounter with this circuit architecture.

REFERENCES

AN686, (1998), *Understanding and Using Supervisory Circuits,* available on the Microchip Technology, Inc., web site:
http://www.microchip.com/download/appnote/super/about/00686a.pdf

MCP100 Data Sheet (DS11187), available on the Microchip Technology, Inc., web site:
http://www.microchip.com/download/lit/pline/analog/power/pwrmang/super/11187f.pdf

MCP120/130 Data Sheet (DS11184), available on the Microchip Technology, Inc., web site:
http://www.microchip.com/download/lit/pline/analog/power/pwrmang/super/11184d.pdf

Sedra and Smith, (1998, 4th edition), *Microelectronic Circuits,* Oxford University Press, Oxford.

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