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Opto Isolation Circuits For In Circuit Debugging of 68HC9(S)12 and 68HC908 Microcontrollers

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Introduction

Motorola's HC08 and HC12 MCUs are widely used in ac line powered applications. In some cases, the MCU uses a non-isolated power supply. Performing in-circuit debugging on ac line powered systems can be tricky and sometimes dangerous due to differing ground connections, floating power supplies, etc. For example, **Figure 1 . Microcontroller Circuit with Low Cost Power Supply** shows an MCU controlling an ac motor. The MCU is powered from a low cost charge pump power supply that is connected directly to the ac line voltage. In relation to earth, the MCU Vdd and Vss pins can reach hundreds of volts. This type of power supply is common in white and brown goods applications, examples of which include vacuum cleaners, fridges, washing machines, light dimmers, etc. If a debugging tool was connected directly to the MCU in this circuit, two possibilities could occur depending on the construction of the tool's power supply.
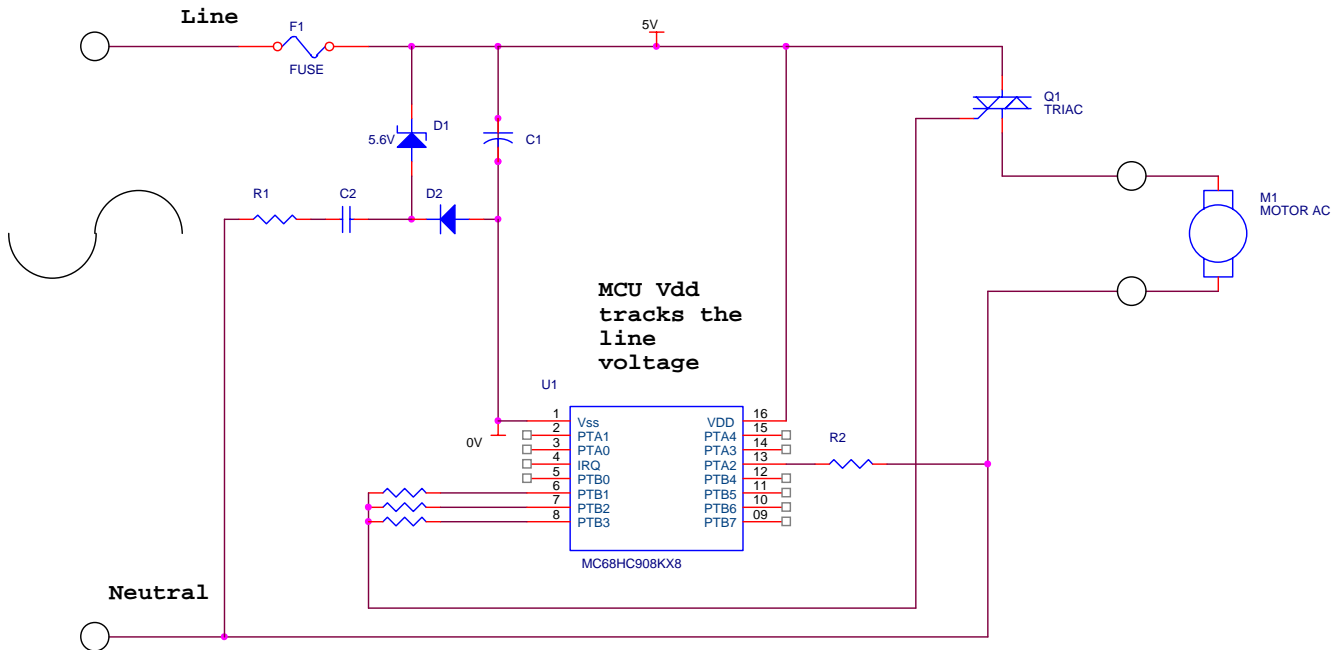
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Figure 1. Microcontroller Circuit with Low Cost Power Supply

If the power supply is isolated from earth, as shown in **Figure 2 . Debugger with isolated power supply**, it will rise to ac line potential in relation to earth. This will raise the potential of the debugging tool to ac line voltage - potentially lethal for the end user. Alternatively, the development tool's power supply output could be referenced to earth as shown in **Figure 3 . Debugger with power supply referenced to earth** and connecting the tool to the application would result in a blown fuse or damage to either the application or the development tool.

For simple applications, engineers have developed non-isolated ac line powered designs by programming windowed EPROMs or flash based MCUs and debugging by trial and error. Basically the engineer had to remove the mcu from the application, erase then reprogram the mcu and put it back into the application. However, by using the powerful in-circuit debugging modes of Motorola's 68HC9(S)12 and 68HC908 microcontrollers in combination with an optoisolated interface, designers can safely develop these applications more efficiently without the risk of damaging their development tools.

This application note shows some circuits that can used to optically isolate input, output and bi-directional digital pins. Debug interfaces for the Background Debug Mode of the 68HC(S)12 and monitor mode on the 68HC08 are also shown.
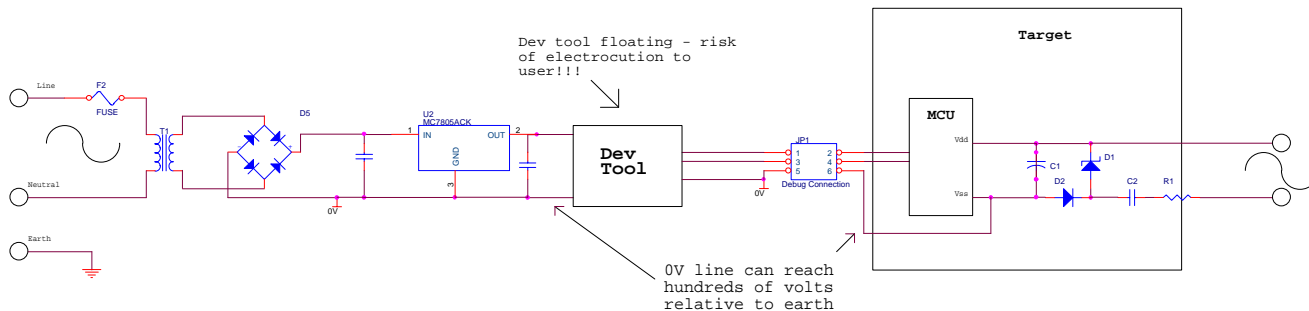
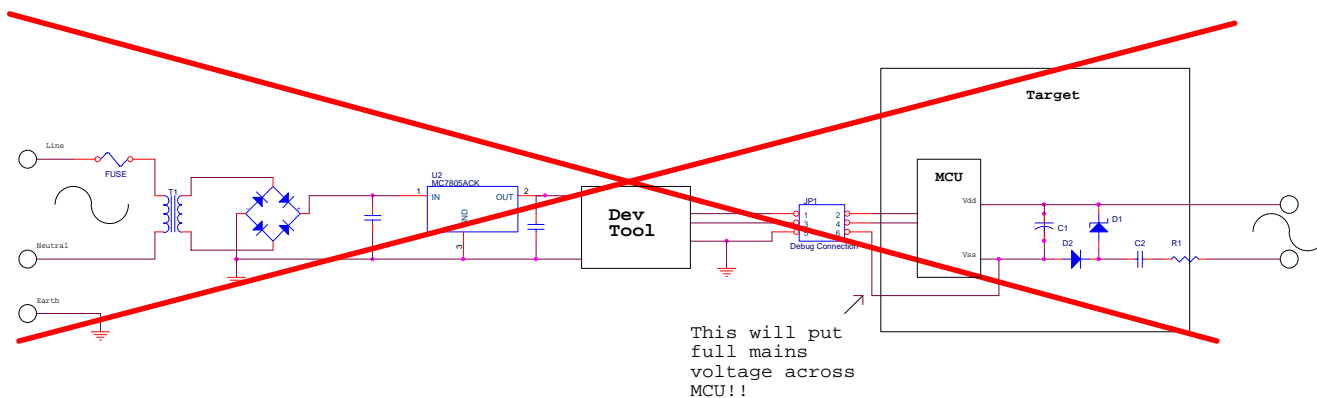**Figure 2. Debugger with isolated power supply**

Figure 3. **Debugger with power supply referenced to earth**

Input and Output Pins

The optoisolation circuit shown in **Figure 4 . Opto Isolation of a unidirectional pin** shows a standard circuit that can be used to isolate a unidirectional digital I/O pin.
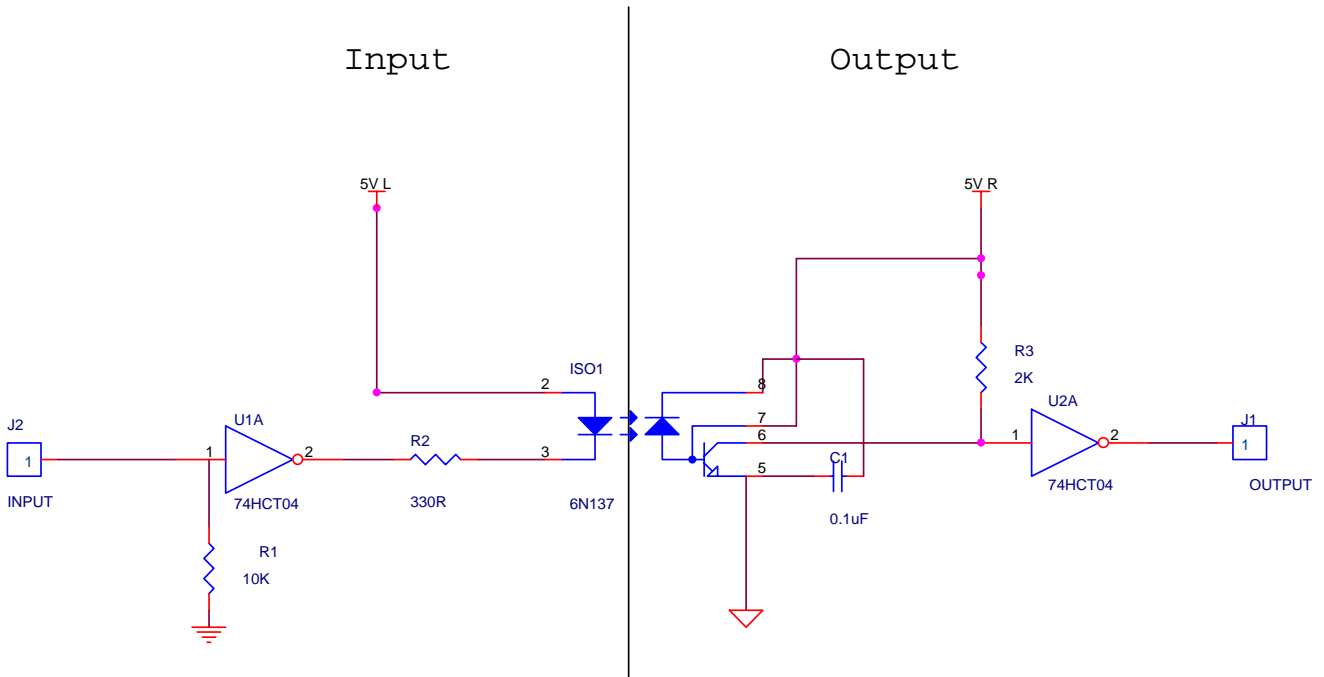
Opto Isolation Circuits For In Circuit Debugging

Figure 4. Opto Isolation of a unidirectional pin

The circuit works as follows: -

- If the input is at logic '1', the output of inverter U1 is low and the LED in ISO1 is lit. This is detected by the photodiode and the optoisolated transistor is switched ON pulling the input of inverter U2 low. The output is then at logic '1'

- If the input is at logic '0', the output of inverter U1 is high and the LED in ISO1 is not lit. The transistor is switched OFF, so the input to inverter U2 is pulled high. The output is then at logic '0'.

- If the input is not driven, for example, if it is connected to a tristated I/O pin, the input value is set to logic '0' by Rx, thus the output is also logic '0'.

In some cases the 2 inverters can be removed provided that the system connected to the input pin can sink at least 15mA current from the LED in ISO1, and the system connected to the output has high input impedance.

Open Drain and Bidirectional Pins

Figure 5 . Opto Isolation of a BiDirectional Pin shows a circuit that allows opto-isolated bidirectional communications on a bi-directional digital pin. It uses 2 x 6N137 optoisolators, 2 PNP transistors and some passives.
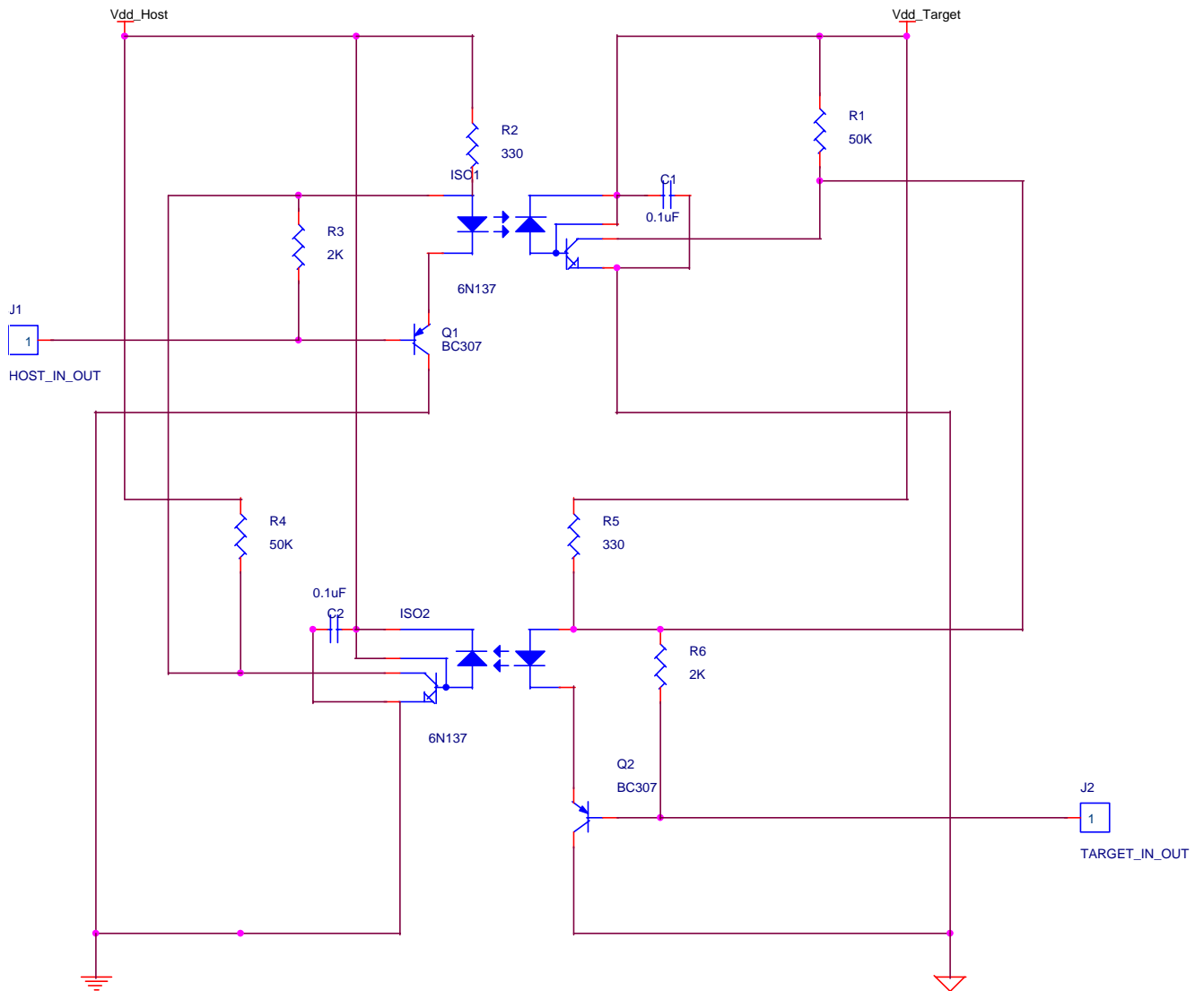

Figure 5. **Opto Isolation of a BiDirectional Pin**

The circuit works as follows: -

- When HOST_IN_OUT is at logic '0', transistor Q1 is ON and the LED in ISO1 is lit. This is received by the photo detector and switches on the transistor in ISO1. This causes TARGET_IN_OUT to be pulled to ground by resistor R6 and also ensures that the LED in ISO2 is OFF. This means the transistor in ISO2 is also OFF.

- When HOST_IN_OUT is at logic '1', transistor Q1 is OFF, The output transistor in ISO1 is OFF. TARGET_IN_OUT is pulled high by resistors R1 and R6. The LED in ISO2 is OFF. Thus there is no feedback to HOST_IN_OUT.

- If HOST_IN_OUT is not driven, for example if it is connected to a tristated I/O pin, it is pulled high by R2 and R3. From the description above, it can be seen that the output will then be high also.

- If both HOST_IN_OUT and TARGET_IN_OUT are not driven, the both pins will be pulled high

The circuit is bi-directional. However, the user should not drive both terminals at the same time. This will not cause any damage to the circuit, but it will increase the current consumption

If the circuit is used to optoisolate an open drain I/O pin, no additional pull-up resistors should be required.

Using the 2 circuits for unidirectional and bi-directional pins described above, it is possible to optically isolate the Background Debug Mode on the 68HC(S)912 mcu family and monitor mode on the 68HC908 family.

Opto Isolation Circuits For In Circuit Debugging

Design Considerations When Using Optoisolation

The designer should consider the following when adding optoisolators to a design for debugging purposes

Power Consumption   A 6N137 optoisolator requires approximately 15mA current to drive its LED. This extra power requirement needs to be considered when choosing voltage regulators or other power supply components. For the bidirectional circuit shown in **Figure 5 . Opto Isolation of a BiDirectional Pin**, under normal operation condition, only 1 optoisolator will be active at any given time, so for this circuit, the designer need only allocate extra current for 1 optocoupler.

Opto Coupler Speed   There are a wide variety of opto couplers available with differing maximum frequencies. The 6N137 optocouplers used in this application note were rated to 10Mbits/s and gave excellent performance when used to isolate the Background Debug Module on the 68HC(S)12 and monitor mode on the 68HC08 (the bit rate of the background debug module is less than 2 Mbits/s and less than 56kbits/s for monitor mode).

Background Debug Connection For 68HC(S)12

Freescale HC12 and HCS12 MCUs provide on chip debugging via the Background Debug Module (BDM). Full details of the Background Debug Module are available in the BDM chapter of each HC(S)12 datasheet.

There are many development tools available that can interface to the BDM module. Most take the form of a small debug cable that connects to a PC through a serial or parallel port. There is usually a 3-wire connection between the debug cable and the BDM module - BKGND, RESET and GND.

- BKGND is a bidirectional pin that allows communications between the HC12 and a debugger.
- RESET is also a bidirectional pin. The debugger can pull reset low to reset the chip. The MCU may reset itself due to an internal operation, for example, a watchdog reset. This needs to be signalled back to the debugger
- GND is the ground connection.

Most debug cables use the Freescale-recommended 6 pin connection shown in **Figure 7 . Freescale Recommended Background Debug Connector**.
Figure 8 . Optical Isolation Circuit for Background Debug Mode shows a circuit that provides optoisolation for the debugging cable using 2 bidirectional circuits as shown in **Figure 5 . Opto Isolation of a BiDirectional Pin**.
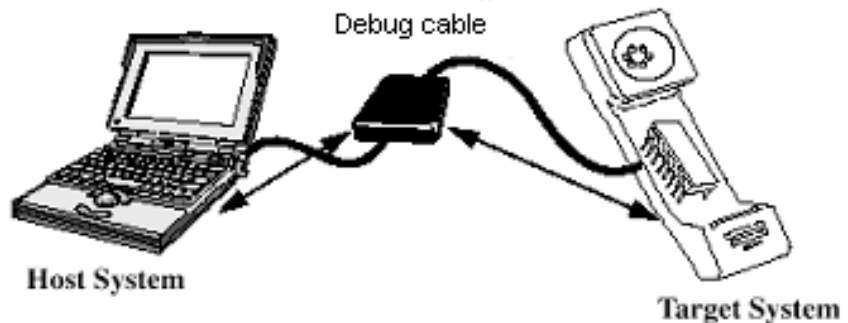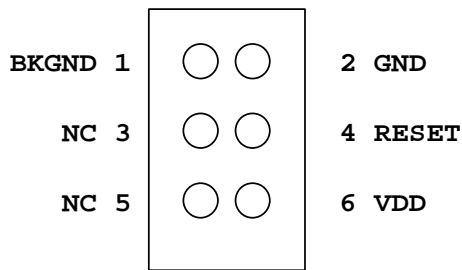

Figure 6. Serial Debug Cable

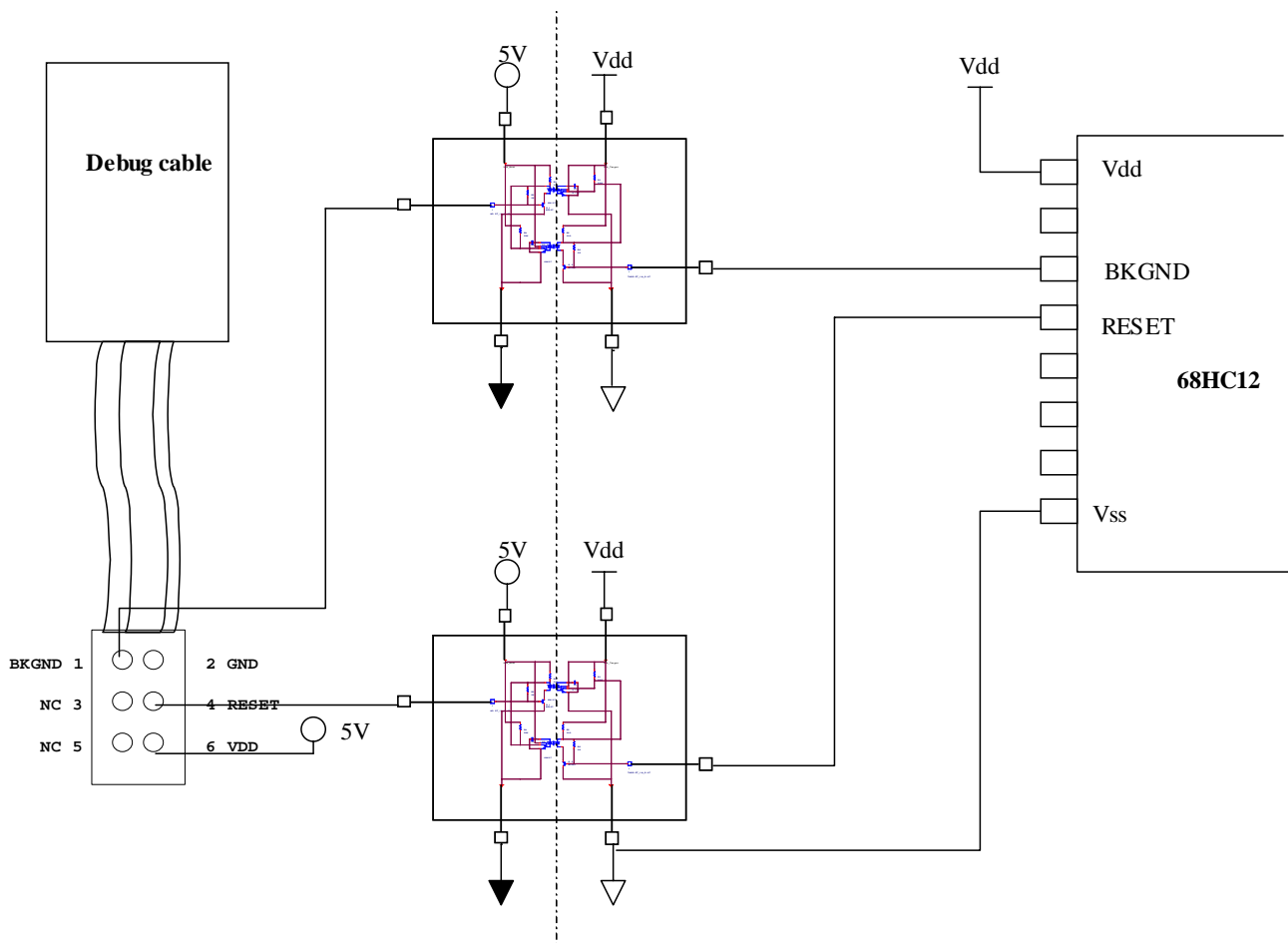**Figure 7. Freescale Recommended Background Debug Connector**

Figure 8. Optical Isolation Circuit for Background Debug Mode

MODA and MODB Pin Control	The engineer can choose to select the operating mode of the 68HC(S)12 when the mcu resets by setting or clearing the MODA and MODB pins on the mcu. Mostly, these pins are hardwired in the application to select a particular mode of operation. However, some debuggers can connect to these pins and provide dynamic control over the operating modes. These pins can be easily optisolated using the circuit shown in **Figure 4 . Opto Isolation of a unidirectional pin**.

Monitor Mode Connections For 68HC08

Figure 9 . HC08 Monitor Mode Connection shows the connections required to access monitor mode on the 68HC908AZ60A and a minimal debugging circuit. For other HC08 mcus the connections may vary, please refer to the monitor ROM chapter in the device datasheet for the exact connection. However, all HC08s require the following minimum connections: -

- PTA0 – a bi-directional data pin used to communicate between the mcu and debugging hardware
- RESET – a bi-directional pin used by the debugger to reset the mcu. It can also be used by the debugger to detect mcu-generated resets (eg, watchdog timeouts). In **Figure 9 . HC08 Monitor Mode Connection** reset is controlled by a switch that the user can toggle to reset the device
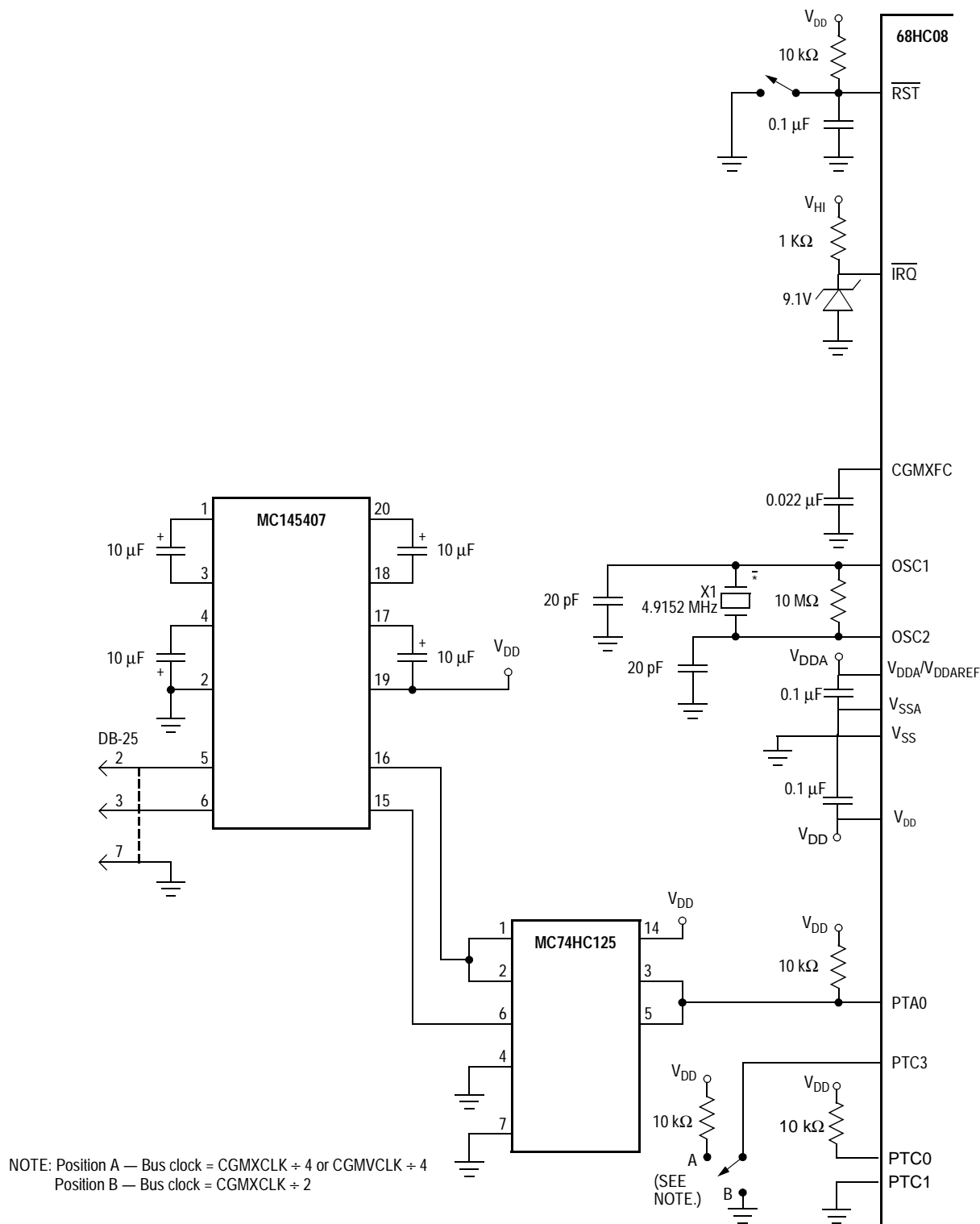
Opto Isolation Circuits For In Circuit Debugging

Figure 9. HC08 Monitor Mode Connection

NOTE: Position A — Bus clock = CGMXCLK ÷ 4 or CGMVCLK ÷ 4
Position B — Bus clock = CGMXCLK ÷ 2

Opto Isolation Circuits For In Circuit Debugging

Other monitor mode pins (PTC0, PTC1, PTC3) can be 'hardwired' to allow monitor mode access, or they could be optoisolated using the circuit shown in **Figure 4 . Opto Isolation of a unidirectional pin**. Note, isolating all the monitor mode set-up pins would involve adding significant additional current requirements on the application's power supply

Figure 10 . Opto Isolation Circuit For Monitor Mode shows the monitor mode circuit with optoisolation using circuits shown in **Figure 4 . Opto Isolation of a unidirectional pin** and **Figure 5 . Opto Isolation of a BiDirectional Pin**.

Figure 10. **Opto Isolation Circuit For Monitor Mode**

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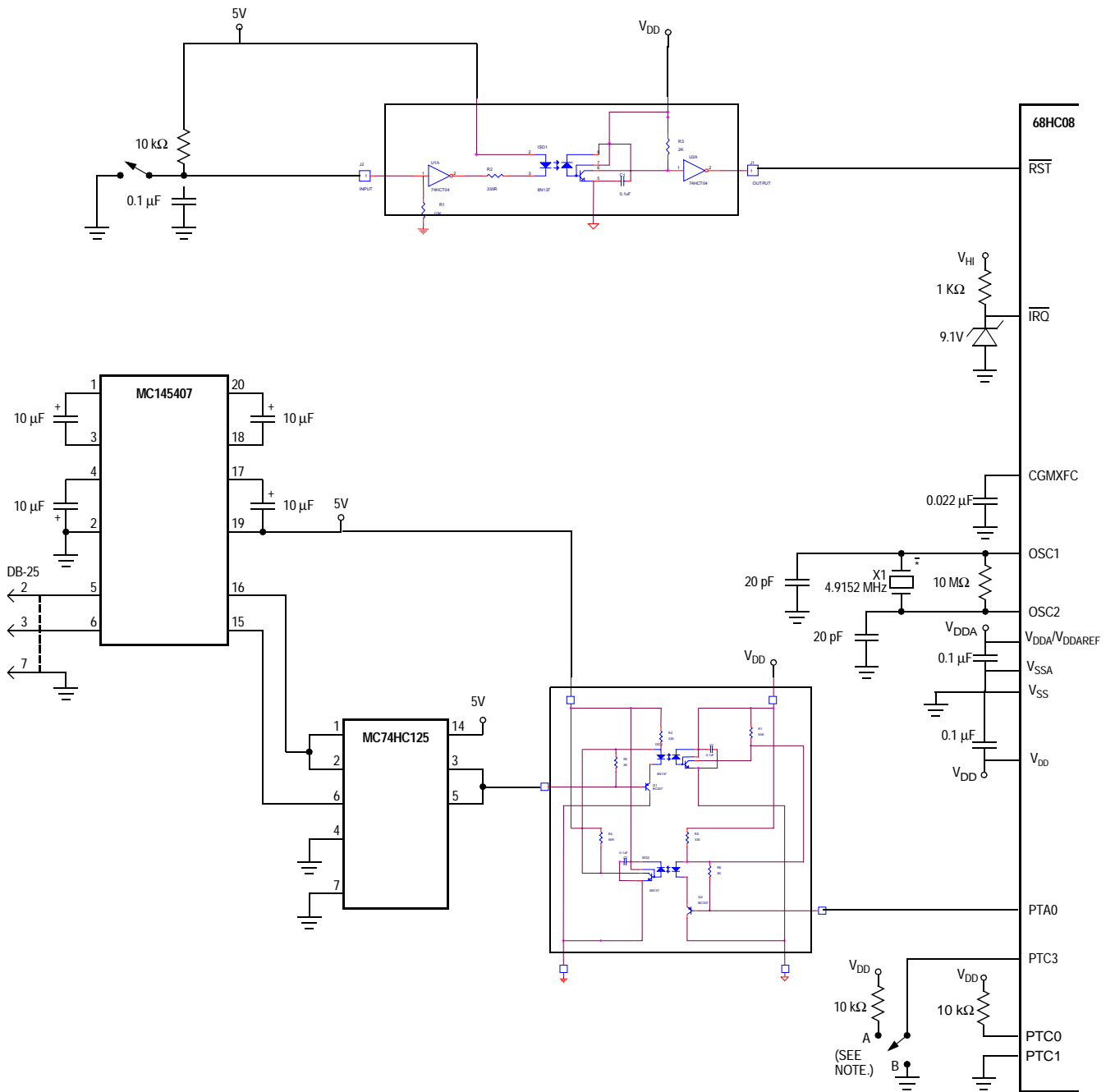
IRQ Pin Control   For correct entry to monitor mode on the 68HC908AZ60A and many other 68HC08 mcus, the IRQ pin must be supplied with a voltage level of Vdd + 4.5V. For debugging purposes when using an optically isolated interface, this voltage can be hardwired on the application board side of the optical barrier. If the user wishes to control switching of the IRQ voltage, it can be achieved using the circuit shown in **Figure 11 . IRQ Pin Optical Isolation Circuit**.
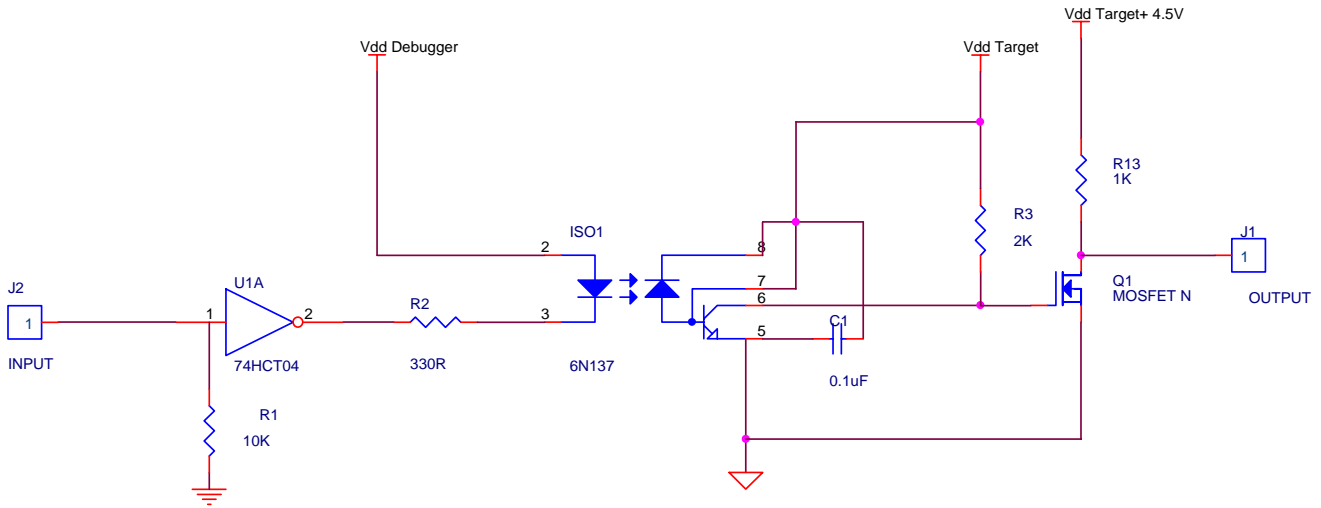
Figure 11. IRQ Pin Optical Isolation Circuit

Summary

This application note details 2 circuits for optically isolating unidirectional and bi-directional digital pins. It explains how these circuits can be used to allow development engineers to safely and efficiently develop non-isolated ac line powered applications.

References

1. M68HC908AZ60A   Technical Data
2. MC9S12DP256   Technical Data

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