Application Report
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# Isolated CAN Solution by Using ISO1050 and SN6501

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**ABSTRACT**

This application note presents a reference design of a compact isolated CAN module by using isolated transceiver ISO1050 and transformer driver SN6501. Compared to current solutions in the industry, this design has the advantages of easy implementation, high reliability, low EMI, and low cost. The ISO1042 can be used as a performance upgrade to the ISO1050.

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## 1 Introduction

Today, along with the fast popularization of CAN-bus, the application field is more diversified and complicated than before. Un-proper node design causes poor communication, and even one node failure can result in damage to an entire bus, especially in a harsh environment. Therefore, essential protection circuit should be implemented into node design to improve reliability and reduce unnecessary damage. For common design, isolation for digital signal and power is added between the controller and the transceiver. In some applications that require higher ESD protection, TVS should be added in the bus.

The current solutions are either too complicated (for example, digital isolator, CAN transceiver, and isolated power) or too expensive. As a viable solution, the combination of ISO1050 with SN6501, a compact, high-performance and low-cost reference design, is provided.


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## 2 Capacitive Isolation Technology

ISO1050 transceiver is an isolated CAN transceiver with a maximum data rate of 1 Mbps and 4 kV of galvanic isolation. The ISO1050 transceiver meets or exceeds all requirements of the ISO 11898 standard. This device uses capacitive isolation technology ($SiO_2$) for signal path isolation. Compared to inductive and optocoupler type, the main advantage of $SiO_2$ capacitive isolation is high reliability and long-life time expectancy, which benefits from its small aging effect characteristic. With an industry lifetime requirement at 400 V (minimum) working voltage, inductive type has only 8 years while capacitive isolator has a significantly longer lifetime of 28 years.

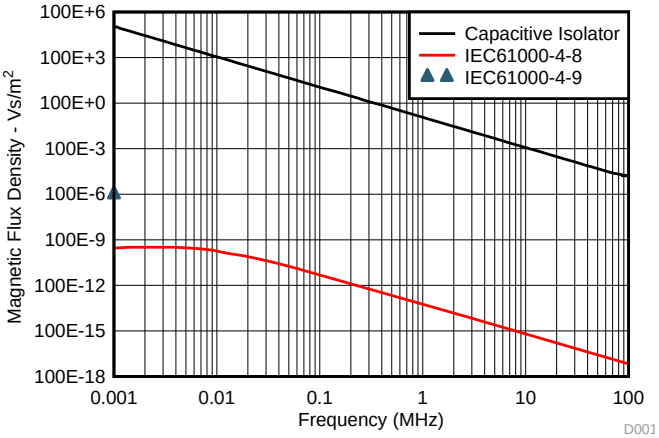


**Figure 1. Magnetic Field Immunity**

Due to internal design construction of capacitive isolators, this type of isolator provides almost infinitely high magnetic field immunity. Figure 1 describes the quantified magnetic immunity (the field-strength is applied without causing false toggling). Figure 1 shows outstanding performance of the capacitive device, which is far beyond the standard of IEC 61000-4-8 and IEC 61000-4-9.

Another benefit of using $SiO_2$ capacitive technology is that it is compatible with standard semiconductor manufacturing processes. Therefore, lower production cost is achieved, thus bringing the lower cost to customer directly.

## 3 Isolated CAN Module Design

For the isolated CAN design, both power supply and signal path must be electrically isolated to meet a certain isolation level. Because ISO1050 is already internal galvanically isolated for signal path, designing a robust isolated power supply is the key design consideration for the entire module. For a common design, isolated power that is glue-poured as a module is always used for convenience (for example, DCR010505, which is a 1-W isolated 5-V to 5-V, DC-DC converter). However, using such a ready-made power module occupies more PCB room and is not suitable in some cost-sensitive cases. A PCB-level discrete solution can also be implemented by using DC-DC converter such as TPS61085; approximately 20 external components, including transformer and diodes, are required. This kind solution is too complicated to design the isolated power supply for a small package-isolated CAN module.

### *3.1 Transformer Driver*

Another more compact, less expensive, and more easily designed method is to use a transformer driver. SN6501 provides this solution. SN6501 uses push-pull topology to drive the transformer; it is designed for low-cost, small form-factor, isolated DC-DC converters. The high primary-side can drive current up to 350 mA at 5-V power supply and 150 mA at 3.3 V with a tiny SOT23 package. Small output capacitor is allowed; this benefits from low ripple on rectified output. Those advantages make SN6501 suitable for isolated interface power supply.


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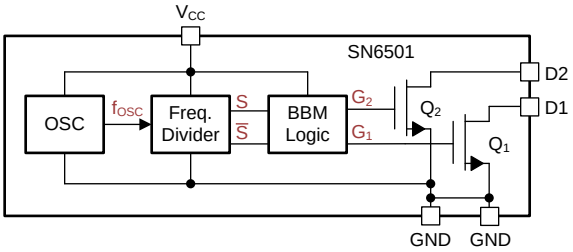


**Figure 2. SN6501 Internal Block Diagram**

Figure 2 shows the SN6501 internal block diagram; it includes an oscillator, a frequency divider, and a break-before-make (BBM) logic. BBM logic outputs two complementary signals, which turn the two output power transistors on and off alternately. Simulation by Pspice model (see Figure 3) shows the complementary push-pull waveform with BBM (Vcc is 5 V with no load at the secondary side of transformer).

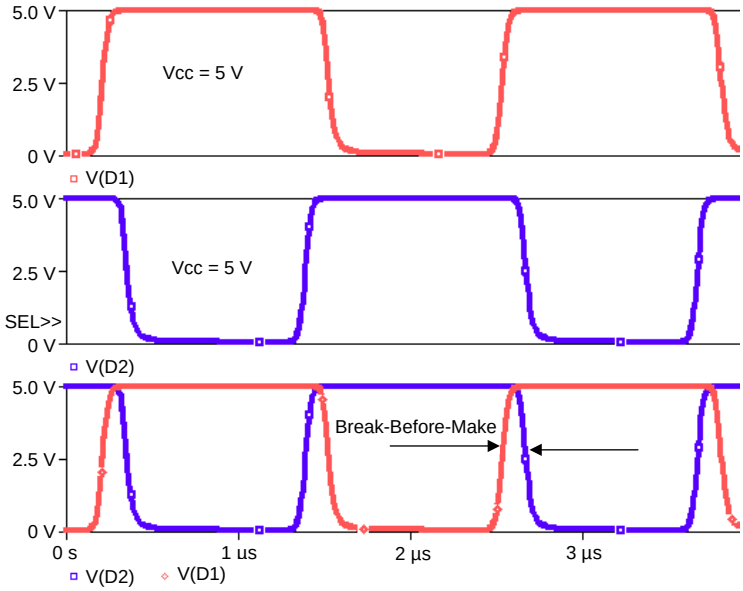


**Figure 3. Switching Waveforms and BBM Waveform by Pspice simulation**

### *3.2 5-V to 5-V Isolated Power Design Consideration*

Figure 4 is the reference schematic for 5-V to 5-V isolated power supply.


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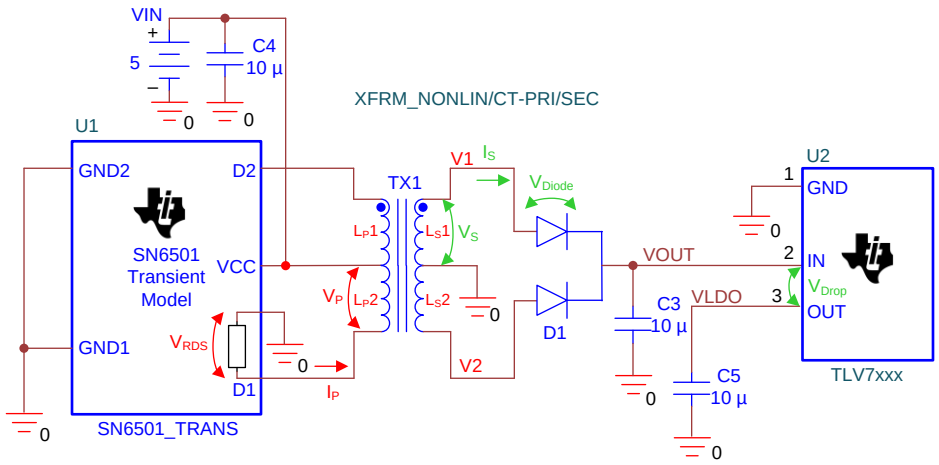


**Figure 4. Reference Design for 5-V to 5-V Isolated Power Supply (Pspice Schematic)**

SN6501 provides low ripple on rectified output. The linear regulator may not be used when the primary side of the transformer is supplied with a stable 5-V power (VIN). However, especially in a safety-related application, such as distributed control systems (DCSs), the programmable logic controller (PLC) and textile machinery controller, ±10% tolerance of VIN should be considered. So, 5-V power supply varies from 4.5 to 5.5 V and output of rectifier (VOUT) also varies with the same ratio. While the power supply at the secondary side (VLDO) of ISO1050 allows only 4.75 to 5.25 V, a 5-V LDO is needed to stabilize the output of the rectifier.

The two main factors to select an LDO are current drive capacity and input voltage range. SN6501 only provides current for ISO1050, thus the current drive capability depends on ISO1050 and should have headroom for the maximum current. For 80 mA (maximum) loading of ISO1050, a 100- to 150-mA LDO, such as TPS70950 or TLV70450, is appropriate.

The transformer output voltage range depends on transformer turns ratio. Minimum VIN and LDO efficiency should be considered to determine the turn ratio. Larger ratio can avoid the LDO step into nonlinear region when VIN drops (VOUT drops accordingly) and maintains a stable 5-V output. However, this results in low efficiency due to a larger drop in voltage on the LDO, and also forces the LDO input voltage to exceed the rating when VIN increases drastically.

Based on the power conservation principle for the transformer,

$$V_P \times I_P = V_S \times I_S \quad (1)$$

Also, according to the same volume of magnetic flux, which flows through the transformer primary and secondary coils, we have:

$$\frac{V_S}{V_P} = \frac{n_S}{n_P} = n$$

- $V_P = V_{IN} - V_{RDS}$ and is the voltage at the transformer primary side.
- $V_S = V_{LDO} + V_{Diode} + V_{Drop}$ and is the voltage at the secondary side.
- $V_{RDS}$ is the drop voltage on the turnon resistor of the SN6501 power transistors, which varies with the changing of the loading current.
- $V_{Diode}$ is the diode forward voltage.
- $V_{Drop}$ is the LDO drop voltage. (2)

Assume ISO1050 with the maximum loading, LDO must provide 80 mA current ($I_{S\text{-}max}$).

$$(V_{LDO} + V_{Diode} + V_{Drop-max}) \times I_{S-max} \quad (80 \text{ mA}) = (V_{IN} - RDS \times I_P) \times I_P \quad (3)$$

$$V_{LDO} + V_{Diode} + V_{Drop-max} = (V_{IN} - RDS \times I_P) \times n \quad (4)$$

To solve this linear equation of two unknowns (n and $I_P$) under below condition: $V_{LDO}$ = 5 V, $V_{Diode}$ = 0.2 V, RDS = 2 Ω (at 5 V). Normally, although a voltage drop of LDO is around 150 mV at 100-mA loading, some low cost LDO has a larger drop voltage. For a worst case, consider $V_{Drop\text{-}max}$ = 1 V (at 100 mA). Gets n = 1.25, $I_P$ = 100 mA.



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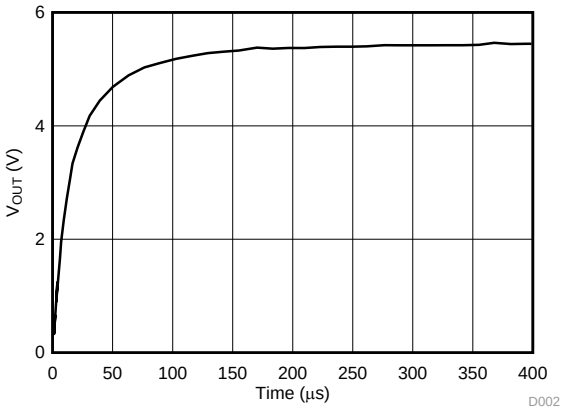
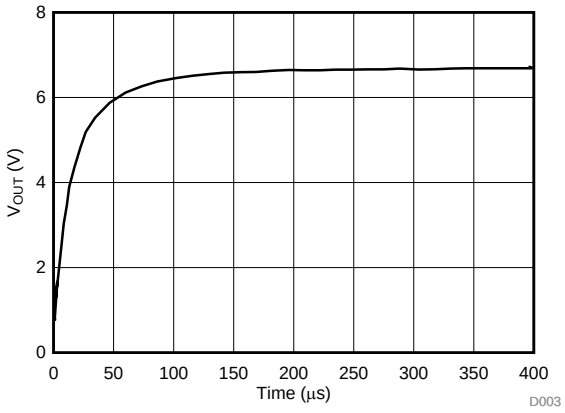
According to the preceding theoretical calculation, if ISO1050 is under the maximum current load, LDO must provide about 80 mA current with a 1-V drop. Turn ratio of transformer should not be less than 1.25. Meanwhile, the maximum primary current provided by SN6501 is 100 mA ($I_P$) which is within the range of 350 mA at 5-V power supply. Figure 5 and Figure 6 show the Pspice simulation when input voltage drops or increases to the design limitation. Based on the simulation and calculation, the minimum transformer output is 5.45 V; thus, it is important to select an LDO with a drop voltage of less than 450 mV at 100 mA maximum loading.




$V_{OUT}$ = 5.45 V

**Figure 5. Transformer Output With Input Drops s –10%**




$V_{OUT}$ = 6.7 V

**Figure 6. Transformer Output With Input Drops s +10%**

## 3.3 PCB Design

To meet 2500 Vrms isolation (isolation level of ISO1050DUB) requirement for the CAN module, besides selecting a suitable transformer, PCB layout must be carefully designed.

PCB creepage distance is the most importance factor to achieve the 2500-Vrms isolation. For ISO1050DUB, the minimum creepage (shortest terminal to terminal distance across the package surface) is about 6.8 mm. Other components (SN6501 at the primary side and LDO at secondary side) should be kept out for this distance. Thus, a small package LDO (SOT-23 or SC70) is better to implement the creepage for small PCB size requirement of the module. The pin connections point of transformer selected also should keep the creepage. Moreover, a slot with the same width of ISO1050 should be cut underneath the transformer (isolation via air). Figure 7 shows the finial outline of the module, which is packaged with glue.

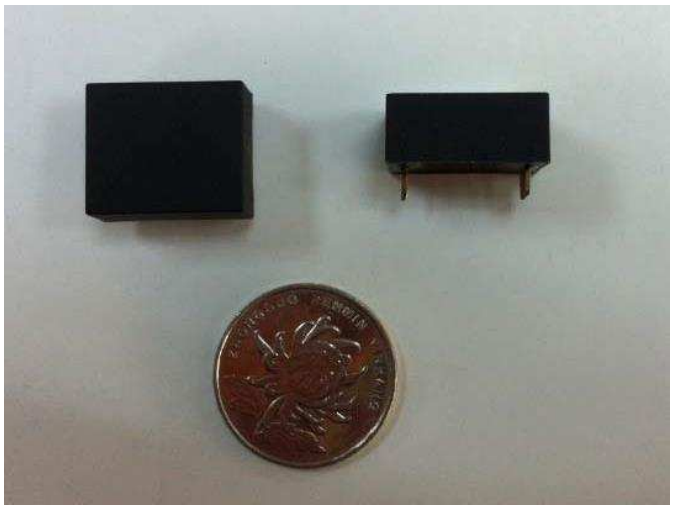


**Figure 7. Front and Side Views of Isolated CAN Module**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## 4 Experiment Validation

To validate the reference design including a 5-V isolated power supply and an entire module communication function, a test bench is set up (see Figure 7). Two MCU control boards are used with essential equipments: 6/2 digit multimeter (34401A-Agilent), oscilloscope (TPS2024- Tektronix), and DC power supply (GPS3303-GWINSTEK).

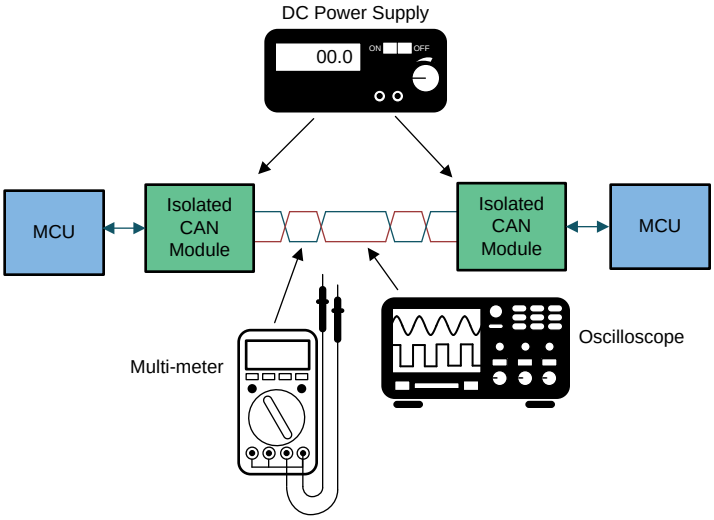


**Figure 8. Isolated CAN Module Test Setup**

A nonisolated CAN device SN65HVD1050 is used as receiver in the experiment to test an isolated CAN module. One MCU sends a prefixed data sequence (handshake) via isolated CAN module. The other MCU receives the data through SN65HVD1050 and checks the error rate at the same time; if an error is found, a green LED on the receiver MCU board turns off. The oscilloscope is also used to observe the CAN bus waveform: 250 Kbps, 500 Kbps, and 1 Mbps data rates are tested and no data errors are found. The second experiment uses two isolated CAN modules as transmitter and receiver, respectively. The same data rates as in the first experiment are tested successfully.

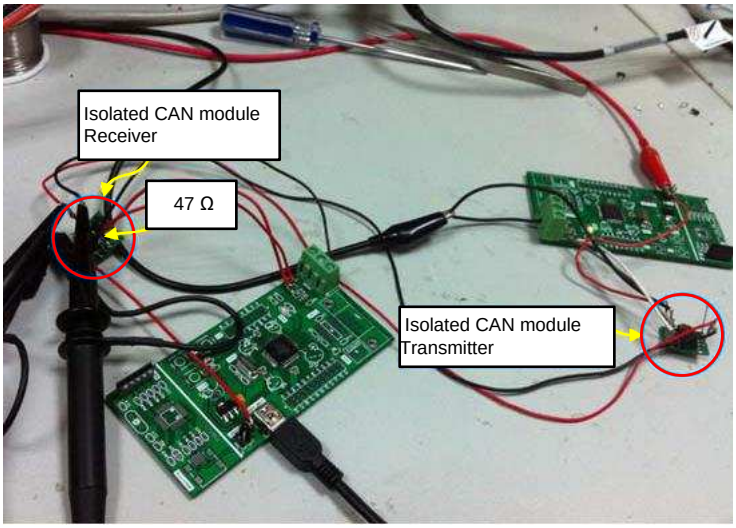


**Figure 9. Fully Loaded bus Test (Waveform of CANH, CANL at a 1-Mbps Data Rate)**


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Bus loading is an important feature for a CAN device. This feature is related to the driver current capacity of a CAN transmitter. Larger output current ability means more nodes can be added on the bus, assuming other conditions remain the same. For isolated CAN, the isolated power supply must provide enough current for the required output swing when the bus is fully loaded. In the CAN standard of ISO 11898-2, the differential output must be greater than 1.5 V with a 60- Ω load, and must be greater than 1.2 V with a fully loaded bus (bus node of a CAN device also depends on receiver differential input impedance besides the driver capacity).

long as the power supply is stable and does not drop when larger current is drawn by ISO1050 with heavy loading, the device can support at least 167 nodes. For this isolated power designed by SN6501, 100 mA on the secondary side is ensured. To test bus loading capacity of the module, a 167-transceiver network is simulated by a resistor. The differential input resistance of ISO1050 is a minimum of 30 kΩ with a maximum of 80 kΩ. Assume 167 nodes are in parallel on a bus with all 30-kΩ resistance: this is equivalent to a 180-Ω differential load. Take two 120-Ω termination resistors into account: this yields a total 45 Ω. In the test, a 47-Ω resistor is shunted on the receiver side. The data rate test is successful at 250 Kbps, 500 Kbps, and 1Mbps. Figure 9 shows the waveform of CANH, CANL at 1 Mbps data rate. The differential output voltage is 2.4 V, which is in the range of 1.4 to 3 V (the value ensured by the data sheet) and also has more margin for 1.2 V (ISO11898-2 requirement).

## 5 Conclusion

An isolated CAN module reference is discussed in this application report. A designer can easily complete a compact, high-reliability, low-cost 5-V to 5-V isolated power by using SN6501 and a few external components. In place of the ISO1050, ISO1042 can also be used as a performance upgrade. Detailed design consideration of how to select LDO and calculate appropriate transformer turn ratio is presented. Meanwhile, Pspice simulation is used to validate the theoretical calculation. Finally, the maximum bus loading (167 nodes) and highest data rate (1 Mbps) is achieved in a set of experiments to demonstrate the robustness of the isolated CAN module.

## 6 References

For related documentation, refer to the following:

- Texas Instruments, *SN6501 Transformer Driver for Isolated Power Supplies* data sheet
- Texas Instruments, *ISO1050 Isolated CAN Transceiver* data sheet
- Texas Instruments, *ISO1042 Isolated CAN Transceiver With 70-V Bus Fault Protection and Flexible Data Rate* data sheet
- Texas Instruments, *ISO72x Single Channel High-Speed Digital Isolators* data sheet
- Texas Instruments, *High-Voltage Lifetime of the ISO72x Family of Digital Isolators* application report


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## Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Original (January 2013) to A Revision | Page |
|---|---|
| • Added the ISO1042 device recommendation | 1 |


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