

Common-mode effects in CAN networks

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Common-mode problems are often found in the networked equipment typically found in CAN applications. Possible effects of this problem are intermittent reboots, lock-ups, random errors, or physical damage to electronic equipment. Interface cards, parallel ports, serial ports, and especially transceivers are prime targets for some form of failure if not designed to accommodate high levels of noise and power supply imbalance between CAN nodes due to common-mode voltage ground offset.

Differential balance and common-mode noise rejection

As the electromagnetic (EM) spectrum becomes more fully utilized by modern equipment, there is an increasing probability of interference in electronics that results from EM fields radiated by a wide range of

devices. Due in part to the revolution in wireless electronics, EM interference is increasingly becoming a widespread concern.

Every electronic component has unique EM characteristics in which the inductance and capacitance of its circuit may develop a common-mode resonance that occurs at discrete frequencies in which emissions are amplified at some frequencies and attenuated at others. EM radiation links the antenna-like wires of a CAN network and generates common-mode noise on the twisted-pair bus lines. However, differential signaling allows CAN to operate in the presence of this common-mode EM noise and at the same time minimize its own radiated emissions. CAN's differential signaling allows the receiver to reject common-mode noise that occurs within the differential input range of the device.

Common-mode noise rejection is a specific function of differential receivers, just as it is with other differential-input circuits such as operational amplifiers. Differential signal wires are physically close together and equally exposed to the same noise sources – noise common to each wire. The close proximity of the wires ensures that exposure to electromagnetic fields is nearly equal and common to each line, thereby canceling the differential influence from magnetic field coupling by reversing the polarity in adjacent loops of twist in twisted-pair wiring.

Common-mode noise due to capacitive, electromagnetic, or inductive coupling from extraneous sources of notable magnitude exist within the networks associated with many CAN applications. Noise from pulse motor controllers, switch-mode power supplies, or from old, ballast fluorescent lighting load are the typical sources of the noise that couple onto bus lines.

The CAN differential signal is the voltage difference between the CAN_H & CAN_L wires, equal to $CAN_H - CAN_L$. For a recessive bit, this is typically 0 V, and for a dominant bit is 2 V (high-speed transmission as specified in ISO 11898-2). Problems often occur when noise nearing this amplitude attaches itself to a bus signal. Unwanted noise of this magnitude often links the antenna-like bus lines of a CAN application as displayed in Figure 1. ▽

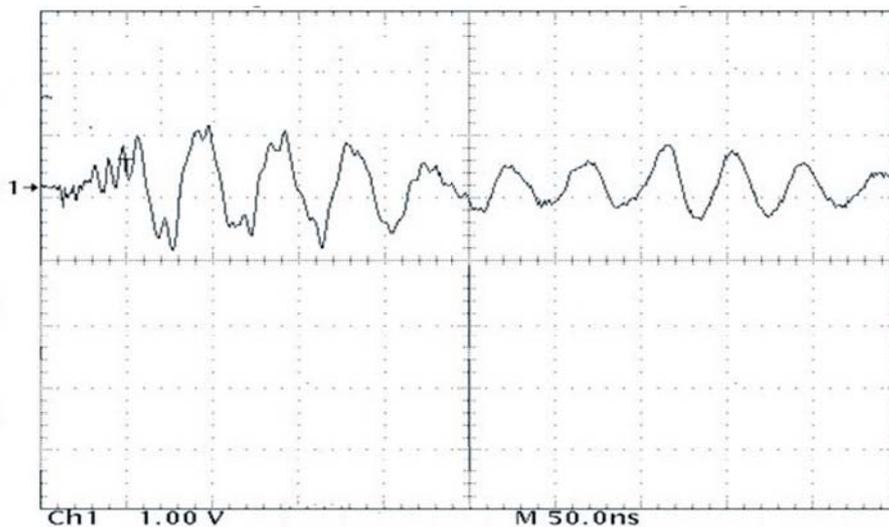


Figure 1: Noise coupled onto twisted-pair bus-lines

When $CAN_H - CAN_L$ does not equal zero as shown in Figure 2, trouble begins. If each wire of a CAN line is not equally coupled by this noise and rejected differentially, a receiver may respond to common-mode noise as if it were data on a bus and send meaningless data to a controller. It is noteworthy that the TI SN65HVD251 datasheet shows how the transceiver is actually tested for coupled noise rejection.

A common-mode noise solution

Passive filtering termination circuits can attenuate the common-mode noise seen at the receiver terminals – common-mode chokes, or

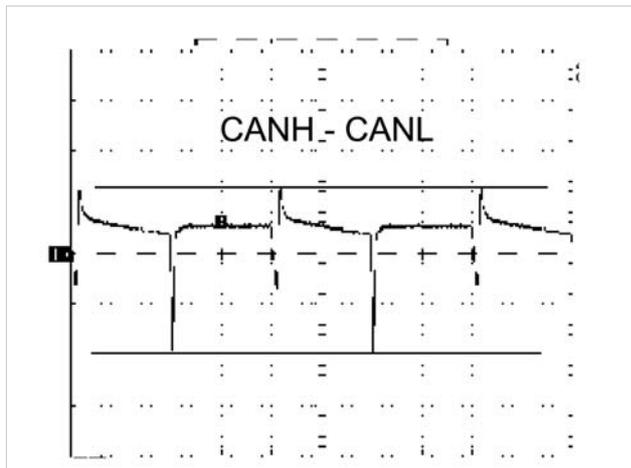


Figure 2: Common-mode noise

baluns are often used for this purpose. However, split termination resistors with a capacitor to ground from the center point, are successfully being used.

To facilitate this function as defined in ISO 11898-5 (high-speed transmission with low-power mode), CAN transceivers such as TI's SN65HVD1040 provide a "Split" pin specifically designed for this purpose with the same common-mode voltage operation and ESD protection as the bus-pins.

Split-termination is used to filter high frequency common-mode noise from the bus lines with the ter-

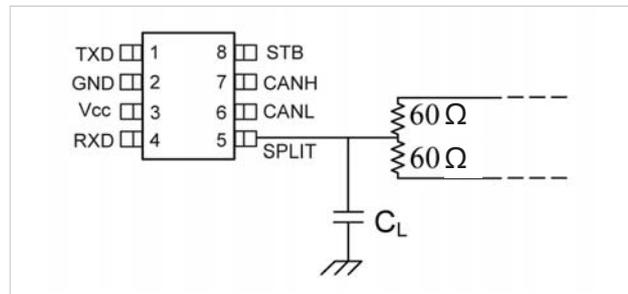


Figure 3: Split-termination filter

mination technique shown in Figure 3. This is accomplished with a coupling capacitor at the center-tap of two 60-Ω termination resistors. This configuration couples high frequency noise to a solid ground potential.

In the split-termination configuration, a differential signal can be understood as the two sources in Figure 4 in series with a center-tap to ground. The upper

tial symmetrical source, these ground currents cancel one another. The grey dashed current now represents the resulting current flow, and there is no influence from the split-termination capacitor in Figure 3 on the differential signal.

A typical value for C_L in Figure 3 as recommended by the ISO 11898-5 standard is 4,7 nF. The capacitor does not limit the bandwidth of the differential signal since it only affects a common-mode noise. This function is being employed so successfully as displayed in Figures 5 and 6 that many designers no longer require chokes.

Common-mode voltage offset

Common-mode voltage offset describes a condition, in which the ground-pin of an electrical outlet thought to be 0 V is found to be at a high DC-voltage level. Currents that flow between the ground plane and earth due to AC primary or secondary neutral currents in a power-distribution system, produce a potential difference between the neutral and ground plane. This

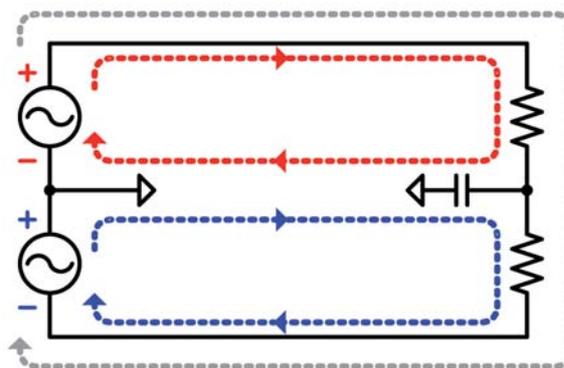


Figure 4: The differential signal with split-termination

Abstract

The term "common-mode" is often misunderstood and used in a variety of topics.

Although many common-mode discussions are centered around amplifiers and data converters, it frequently plays a critical role in the operation of a CAN network.

Common-mode problems arise from several sources and are often the cause of trouble in many circuits. This discussion centers on the common-mode noise and common-mode voltage offsets that plague many CAN applications.

Balun

A balun is a type of electrical transformer that can convert electrical signals that are balanced about ground (differential) to signals that are unbalanced (single-ended), and the reverse. They are also often used to connect lines of differing impedance. The origin of the word balun is bal(ance) + un(balance). Source: Wikipedia

Conclusion

The increasing complexity of manufacturing requirements along with demands for flexible, intelligent and fault-tolerant control systems are moving away from the traditional, sequential and centralized 4-20 mA type solutions. This is especially due to the lack of flexibility of these older systems with respect to a quick adaptation on unexpected and continual changes in the manufacturing environment.

CAN common-mode tolerance and flexibility not only brings the ability of integrating of new components into a system or removal of existing ones from a system at runtime, but its high degree of fault confinement minimizes the possibility of module failure and costly downtime in a system.

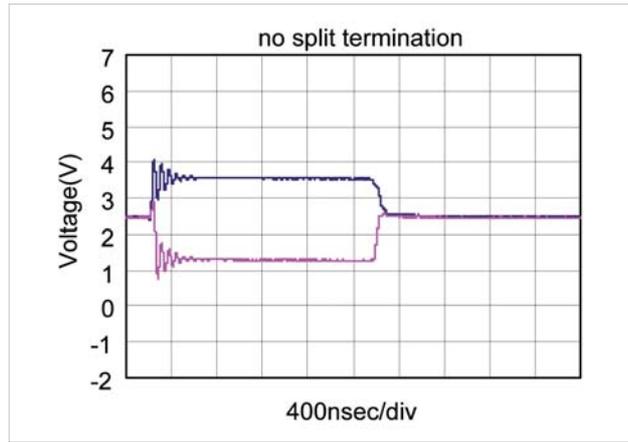


Figure 5: Differential signal with noise

ground offset potential difference between electric power outlet locations can vary widely across any building and must be checked by designers in any CAN application.

Ground voltage offset can vary from several volts to several tens of volts with the greatest differentials found in single-phase or 3-phase Y-distribution systems. In these applications, the portion of neutral current flowing in the earth can be 10% to 70% of the total current flowing in the primary circuit. Voltage measurements between ground points have been reported as high as 65 V between widely separated electrical outlets with disastrous effects on semiconductor products.

CAN transceiver often have to operate in such harsh environments and although the ISO 11898-2 standard specifies operation from -2 V to 7 V, trans-

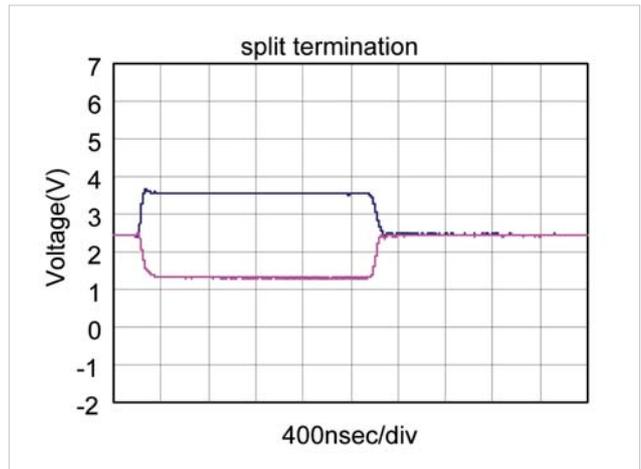


Figure 6: Split-termination filtered differential signal

ceivers such as Texas Instruments' SN65HVD251 operate with -7 V to 12 V common-mode operating range. The differential CAN signal rides an offset voltage as if floating on water until a -7 V or 12 V limit is reached. At this time the transceiver shuts down into a self-protecting high-impedance state and remains safe to 36 V for an unlimited period of time.

A common-mode voltage offset solution

In order that the current required from an active CAN driver be limited to a practical value while driving a signal into 12 V of common-mode voltage, the loading effect of any combination of passive receivers and transceivers on a bus should be held to a minimum by restricting the common-mode voltage pres-

ent. If the amount of DC-current that a device sources or sinks to a bus over the -7 V to 12 V range of common-mode operation is kept to a minimum, the number of nodes that can be added to the bus increases dramatically.

The most popular defense against the varied and problematic ground offset voltage is the practice of carrying the power and ground wires along with the CAN signal wires as shown in Figure 7. If this configuration is used, over a hundred nodes may easily be added to a bus. Several power supplies are often required in large applications and are most efficiently located together in the center of the location and grounded to a common return. Equipment too large to operate from these supplies are connected to a separate power supply, then isolated from the bus lines with digital isolators such as TI's ISO7221. ◀

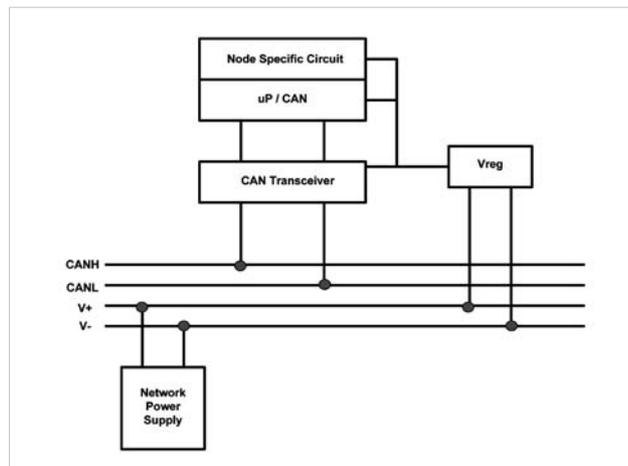


Figure 7: A common-mode voltage solution