Data transmission is faster with ternary coding

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Although data is usually transmitted in binary form, much faster bit rates can be realized, even over long distances, if the data is converted to ternary form. With optimized filters and sensitive receivers, for instance, a ternary data transmission system can achieve an effective rate of up to 6 megabits per second over a 1-mile line of ordinary twisted-pair cable.

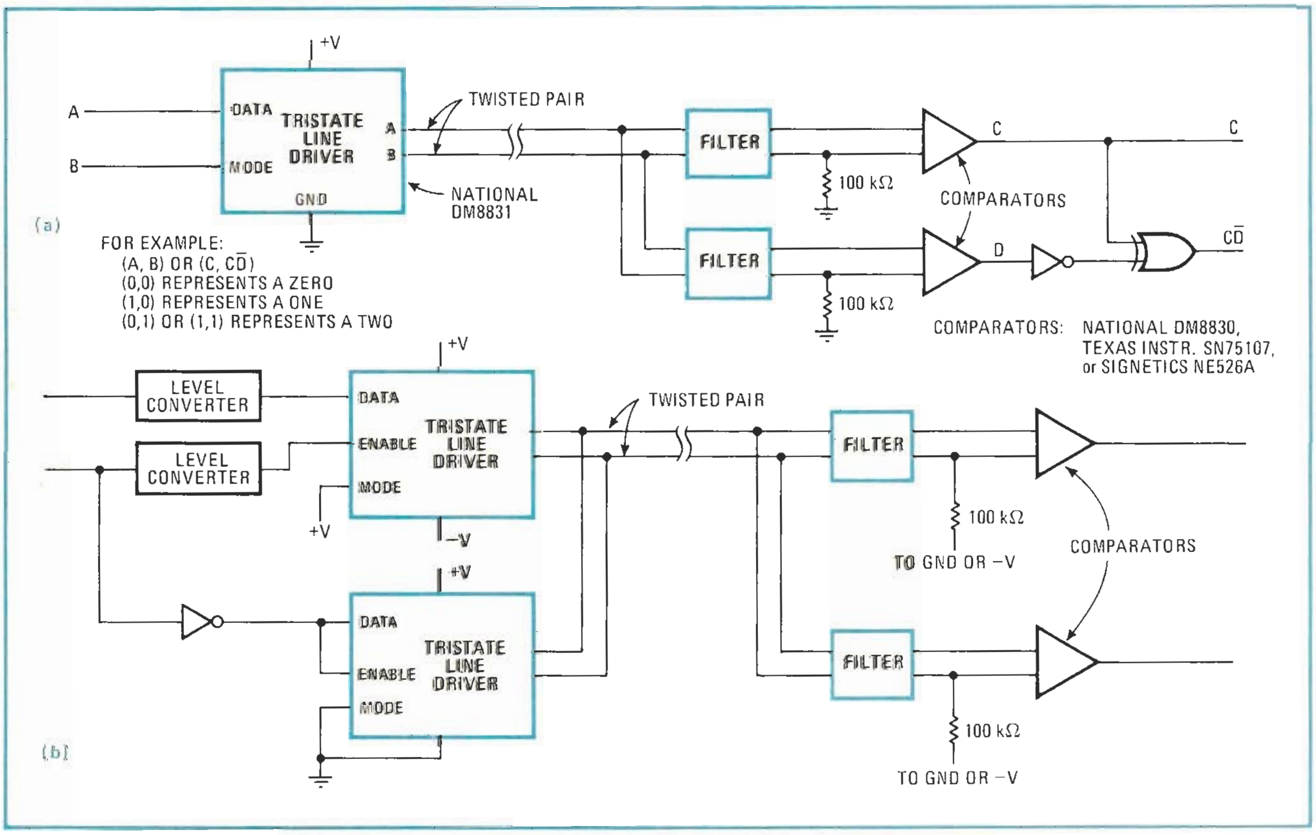
Although twisted-pair drivers have been around for quite some time, they have only been used to carry binary information. Here, logic 1s and logic 0s are defined by the two opposite polarities on the two transmitter outputs. Decoding these voltage differences into ordinary TTL levels is normally done with voltage comparators. The common-mode noise immunity that this system offers has made it one of the most popular transmission techniques in recent years.

Strangely enough, however, nobody has considered the usefulness of a third state, which would still retain a certain immunity to common-mode noise. This state is defined by the absence of any voltage difference at the transmitter outputs. It is primarily useful for sending ternary-coded data over long distances. In case bit speeds are of no great importance, binary data could still be transmitted in the conventional way. The third state would then be used for status information or for system synchronization.

There are several ways of implementing a ternary data transmission system. Over distances of a mile or more, special-purpose balanced line drivers providing a choice of differential or single-ended operation must be used. In these cases, a tristate line driver like National Semiconductor's DM8831 unit is a good choice. The single-ended state may be detected with biased voltage comparators.

If two comparators are used, biased, for example, to different polarities, the third state can be decoded with a mere exclusive-OR logic operation, as shown in (a). This is a simple scheme for low bit rates. It is particularly useful if status or control information is transmitted on the same twisted pair as the data but must nevertheless be distinguished.

For very long lines or for transmission rates of greater than 1 megabit per second, it is best to use two tristate line drivers, establishing a grounded symmetrical transmission system. The three states are easily generated



Getting more out of a twisted pair. Ternary-coded data can be transmitted at megabit rates through ordinary twisted pairs over long distances. A single integrated tristate line driver can be used to send the data at low bit rates, as in (a); or two drivers can be employed, as in (b), for higher bit rates. If desired, the third state can be used for synchronization purposes or to transmit status or control information.

with two line drivers, as in (b). One driver operates differentially (at –2½ and +2½ volts, instead of the usual 0 and 5 V), while the other driver operates in its single-ended mode at normal voltage in a complementary fashion.

To change binary-coded data into ternary-coded data does not require an excessively complicated conversion circuit. Consider, for example, that a fully decoded 16-bit binary word reduces to 10 ternary bits—$(1\ 111\ 111\ 111\ 111\ 111)_{base2} = (1\ 022\ 220\ 020)_{base3}$. In this case, full code conversion provides a bit reduction of 10/16. This means that a ternary-coded transmission system that is able to carry 4 megabits per second of binary-coded data now can effectively carry 16/10 times more information, or 6.4 megabits per second.

Code conversion can be simplified greatly if the binary bits are coded in subgroups. If two binary bits are taken as a subgroup, two ternary bits are required to convert each subgroup. But if subgroups of three binary bits are used, again only two ternary bits are needed (since $111_{base2} = 21_{base3}$) and, therefore, 16 binary bits can be coded into 11 ternary bits.

One application for a ternary transmission system is the use of ternary parity bits. Since there are three states (instead of two), two flip-flops (instead of one) are required. The parity check, then, can just be the modulo-3 addition of the information bits. In this way, a large number of even errors will be detected, but not all odd errors.

With k free binary bits as information carriers and n – k dependent ternary error detection bits, there are 2^k information words out of $2^k \times 3_{n-k}$ possible bit combinations. Therefore, the ratio of nondetectable errors to all possible errors will be: $(2^k - 1)/(2^k 3^{n-k} - 1)$, which approximately equals $\frac{1}{3}^{n-k}$. If one single ternary parity check is used, then two thirds of all possible errors will be detected, instead of only half the errors, as in the case of the modulo-2 parity. □