CY7B8392 Low Power Ethernet Coaxial Transceiver Application

This application note describes the differences between the 10BASE5 (Ethernet) and 10BASE2 (Cheapernet) versions of the IEEE 802.3 standard, and provides guidelines for design with the CY7B8392.

Introduction

The CY7B8392 is a physical layer device used to transmit data over a shared coaxial medium. It functions as specified by the IEEE 802.3 standard.

Figure 1 shows a block diagram of a single network node. The MAC (Media Access Control) is responsible for framing data and controlling its transmission and reception on the network. When transmitting the MAC sends NRZ data to the Physical Signaling (PLS) Layer. The PLS processes the MAC sublayer data, setting the signaling rate and translating the NRZ data to Manchester Encoded Data, and sends it to the transceiver.

Figure 2 displays an example of Manchester encoding. Instead of straight binary encoding, each bit period is divided into two equal intervals. To send a one, the voltage is HIGH (ground) for the first half of the interval and LOW (–2.0 V by IEEE 802.3) for the second half of the interval. In the case of a binary zero the reverse is true, the first half of the bit period the signal is LOW and HIGH the second half.

Data is sent out over the network in packets. An Ethernet packet consists of the preamble, destination address, source address, length field, data, and a Cyclic Redundancy Check (CRC). Each packet can be viewed as a sequence of 8-bit bytes, with the least significant bit of each byte being transmitted first. A typical Ethernet packet is shown in *Figure 3*. The ***preamble*** contains 8 bytes of alternating ones and zeros, ending with two consecutive ones. The preamble allows the receiving PLS to synchronize its clock with the sender. The two consecutive ones at the end of the preamble signify the start of frame packet and are sometimes referred to as the Start of Frame Delimiter. The ***destination address*** is a 6-byte field that specifies the station(s) to which the packet is being sent. Every station examines this field and determines whether it should accept the packet. The high-order bit of the destination address is a zero for ordinary addresses and one for group (multicast) addresses. Group addresses allow multiple stations to listen to one address. The ***source address*** is a 6 byte field that contains the unique address of the station that is transmitting the packet. The ***length*** field is used to determine how many bytes are in the data field. This is necessary because IEEE 802.3 dictates the data portion of a packet must be a minimum of 46 bytes. If the data portion of a packet is less than 46 bytes, it is padded with random bits until it is the legal size. The length field is used to notify the controller

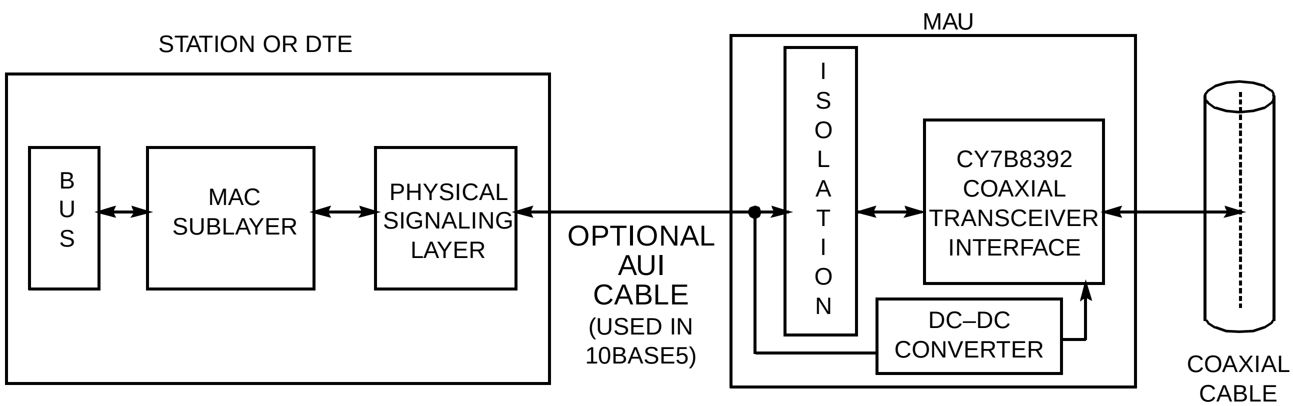

Figure 1. Block Diagram of Single Network Node

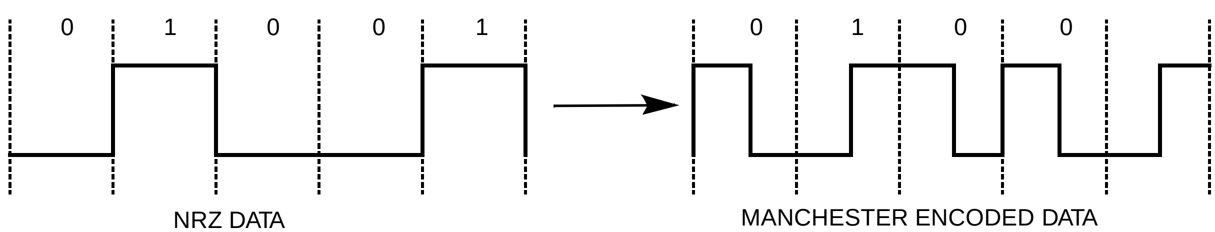

Figure 2. Manchester Encoding

Cypress Semiconductor Corporation • 3901 North First Street • San Jose • CA 95134 • 408-943-2600
November 9, 1995

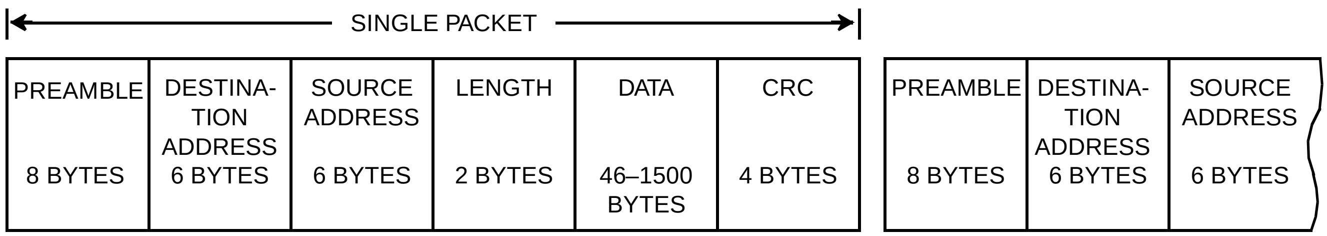

Figure 3. Typical Ethernet Packet

which part of the data field is valid. The ***data*** field contains an integral number of bytes ranging from 46 to 1500. The ***CRC*** field contains code that checks on the integrity of a packet.

10BASE5/10BASE2 Ethernet Network

IEEE 802.3 standard allows for two different versions of coaxial data transmission, 10BASE5 and 10BASE2. 10BASE5 (Ethernet) uses thick coaxial cable with transceivers directly attached to the cable network. Because of the inflexibility of the thick coaxial cable an AUI drop cable is needed to electrically connect the Ethernet transceiver to the Data Terminal Equipment (DTE). IEEE standard allows up to 500 meter lengths of RG–8 coaxial cable to be used in 10BASE5 applications. 10BASE2 (Cheapernet) uses a thin, flexible cable which can be directly attached to the DTE or a Medium Attachment Unit (MAU). A maximum of 185 meters of cable is allowed when using 10BASE2. *Figure 4* and *Table 1* show the differences between Ethernet and Cheapernet (sometimes referred to as Thinnet).

Table 1. Comparison of 10BASE5 and 10BASE2 Media

	10BASE5	10BASE2
Cable type	RG–8	RG–58 A/U
Maximum cable length	500 meters	185 meters
Maximum network length	2500 meters	925 meters
Attachments per segment	100	30
Attachment spacing	2.5 meters	0.5 meters
Topology	Linear bus	Linear bus

Due to the inflexibility of the thick coaxial cable it is difficult to bring the cable directly to the DTE. To solve this problem an AUI drop cable is used in 10BASE5 applications. The AUI cable consists of four individually shielded twisted pairs with an overall shield covering these pairs. The twisted pairs have a characteristic impedance of 78 ±5Ω. The cable can be up to 50 meters in length. The individual shields should be connected to logic ground while the outer shield should be connected to chassis ground. The signal assignments for the AUI twisted pairs are shown in *Table 2*. AUI drop cable is typically not used in 10BASE2 applications because the thin coaxial cable is flexible enough to be directly attached to the DTE.

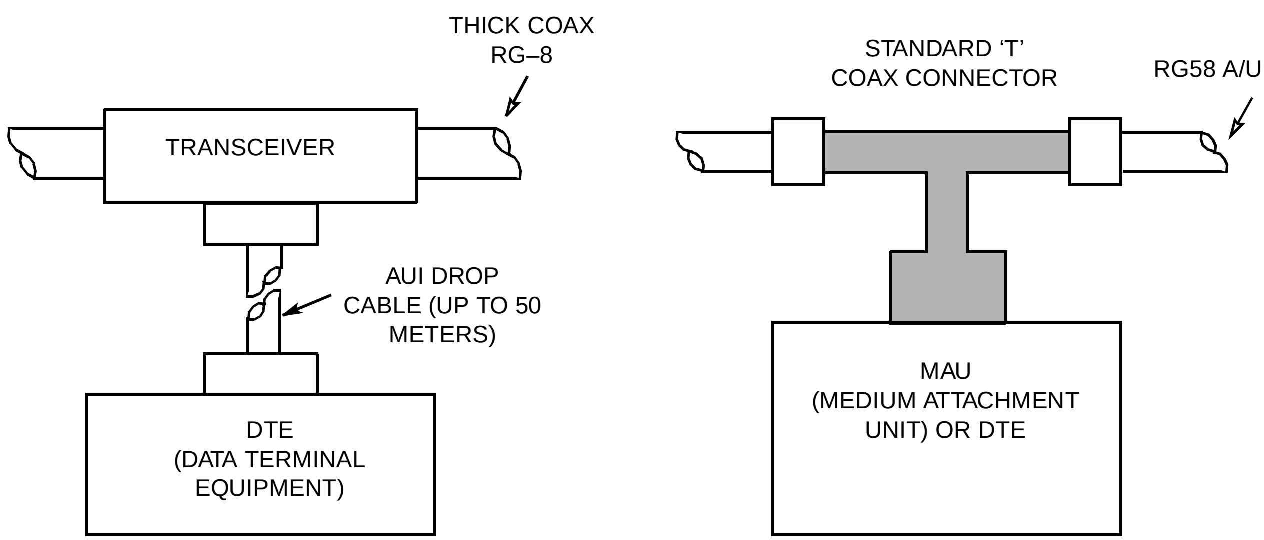

Figure 4. Ethernet vs. Cheapernet

Table 2. AUI Interface Signal Assignments

Pins	Signal	Description
1	Control In circuit Shield	Shield for CD± twisted pair
2	Control In circuit A	CD+ signal
3	Data Out circuit A	TX+ signal
4	Data In circuit Shield	Shield for the RX± twisted pair
5	Data In circuit A	RX+ signal
6	Voltage Common	
7	No Connect	
8	No Connect	
9	Control in circuit B	CD– signal
10	Data Out circuit B	TX– signal
11	Data Out circuit Shield	Shield for the TX± twisted pair
12	Data In circuit B	RX– signal
13	Voltage Plus	Voltage supply from DTE
14	Voltage Shield	
15	No Connect	

It is possible, through the use of repeaters, to combine several networks together. These networks can be a single Physical layer, i.e., only 10BASE2 or only 10BASE5, or it can by a combination of many different Ethernet physical layers. The maximum length of a 10BASE5 network using repeaters is 2500 meters, while the maximum length of a 10BASE2 network with repeaters is 925 meters. *Figure 5* shows a com-

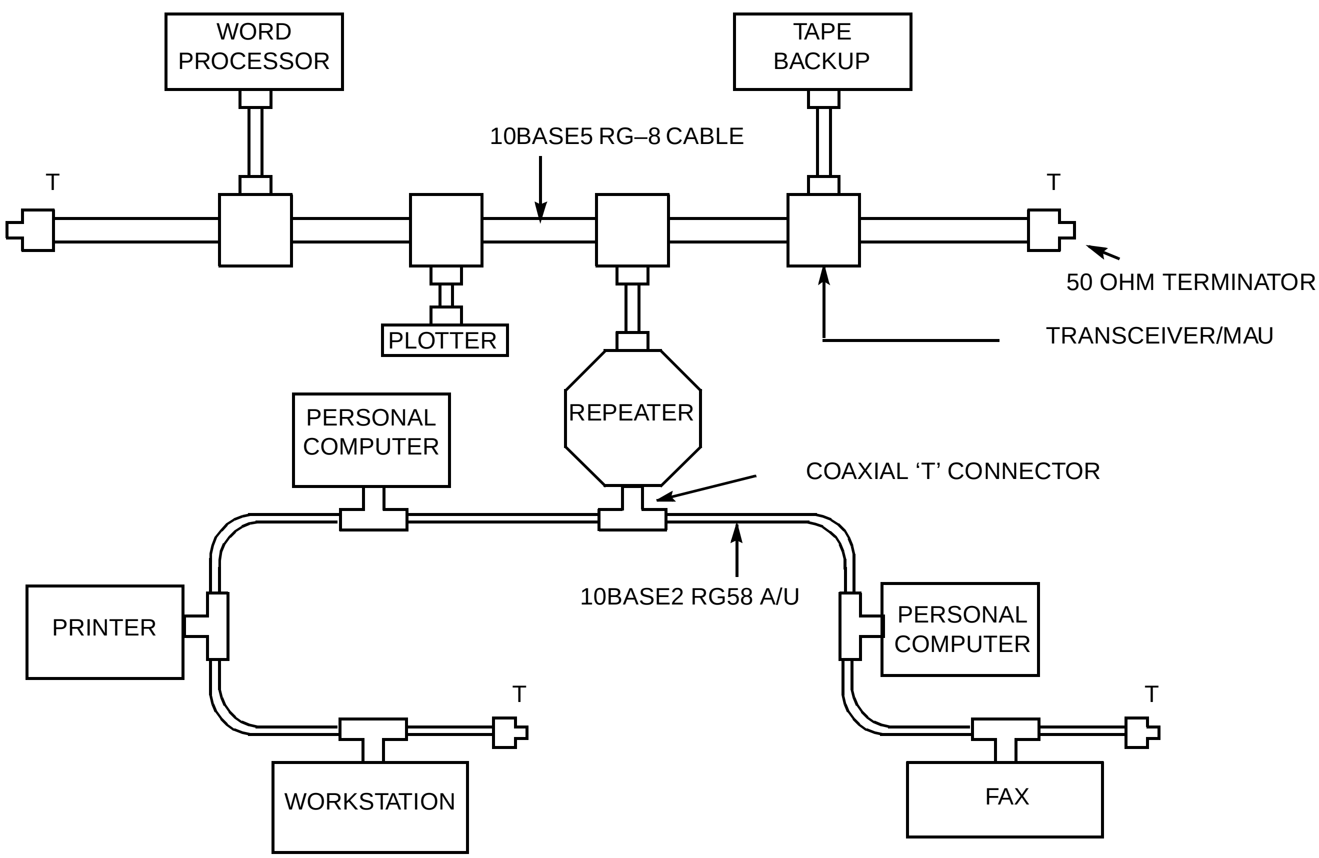

Figure 5. Combined Ethernet and Cheapernet Network

bined network with both Ethernet and Cheapernet connected through repeaters.

CY7B8392 Signal Transmission/Reception

During transmission, differential Manchester encoded data is sent to the CY7B8392 from the DTE. This data is shaped to meet IEEE signal requirements and sent out single-ended onto the coaxial cable. Conversely, when the transceiver is receiving data from the coaxial cable it takes single-ended Manchester encoded signal from the cable and sends differential data to the DTE.

In order to visualize the operation of a 10BASE system using the CY7B8392, we will follow a signal from transmission to reception. When the DTE decides to send a packet, the controller sends NRZ data to the SNI, which in turn sends differential Manchester encoded data through an isolation transformer to the CY7B8392. The transceiver and the coaxial network must be electrically isolated from all external signals. The isolation is required to be 500 V_{AC} for 10BASE2 and 2000 V_{AC} for 10BASE5. This isolation can be performed using three pulse transformers, which are available in 16-pin DIP and 16- or 12-pin surface mount packages available from several manufacturers (Pulse Engineering, Valor Electronics, Bel Fuse). After the differential signal passes through the transformer it is received at the TX± ports of the CY7B8392.

This signal must have an AC signal amplitude greater than –225 mV and a pulse width of more than 15 ns. If these values are not met, the transmitter squelch circuitry will not allow the signal to reach the output driver. The differential signal is sent to a comparator with hysteresis. Every differential voltage crossing flips the output of the comparator which triggers the internal waveform shaping circuitry. The waveform shaping circuitry, feeds a current amplifier which sinks 10 mA (LOW) and 75 mA (HIGH) into the TXO port. Because the network appears as a 25Ω load (two 50Ω resistors in parallel), this translates to a single-ended voltage swing of –0.25V to –1.875V at TXO.

By IEEE 802.3 specifications, the DC offset of the output driver should be between –37 mA and –45 mA. The AC swing should be from ±28 mA up to the offset value. This current drive limit must be met even in the case of one other unit transmitting on the network. The 10–90% rise/fall times must be 25 ±5 ns at 10 Mb/s and they must match within 2 ns.

On the other end of the network data is received from the coaxial cable at the RXI port. The signal is the equalized and amplified before being sent out of the RX± ports. Due to the low pass characteristics of the coaxial cable, equalization of the signal is necessary before it can be amplified and sent to the DTE. The CY7B8392 receiver circuitry has a high pass filter which compensates for the cable characteristics and sends equalized differential Manchester encoded data to Physical Signaling Layer through the RX± ports. In addition to the equalizer, the receiver has a carrier sense feature which will reject signals with less than 467 mV DC content. *Figure 6* depicts CY7B8392 transmission and reception over the network.

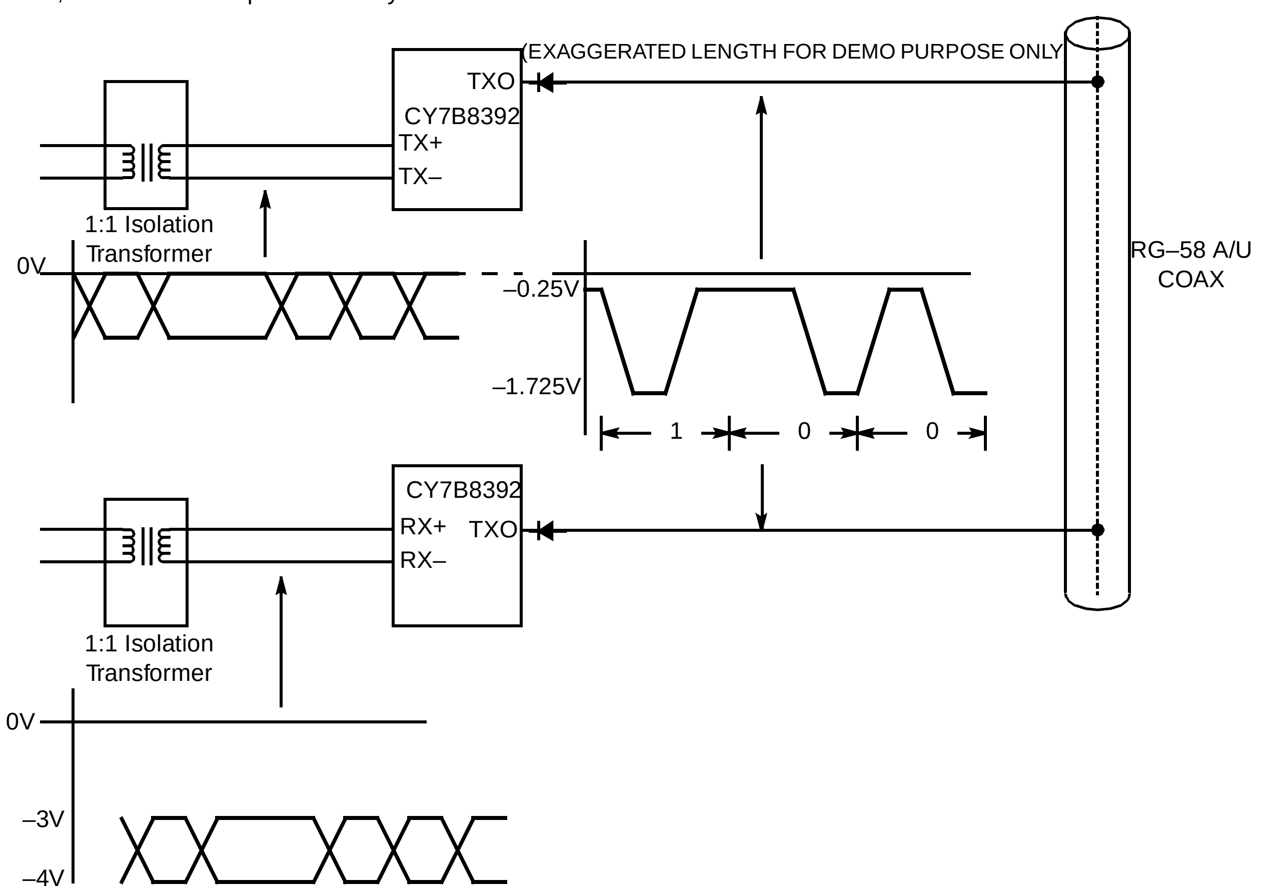

Figure 6. CY7B8392 Transmission and Reception over the Network

Jitter

A characteristic of transmission over a coaxial network is system jitter. Jitter is defined as the short term variations of a digital signal from its ideal position in time. In other words, a clock may be expected to have a rising edge at time t=0, but instead the rising edge occurs slightly after or before t=0. Jitter can be caused by many parts of a network such as source clock imperfections, cable distortion, etc. If the length of the network is large then the low pass filter characteristics of the cable can induce a significant jitter by attenuating the higher frequencies more than the lower frequency signal content. The maximum system jitter allowed by IEEE 802.3 standards is ±7 ns. Minimizing jitter allows the MAC sublayer devices to accurately process data received from the CY7B8392. If the jitter is too great then the bit error rate may increase above acceptable levels.

Collision Detection

Because 10BASE2 and 10BASE5 transmit over a shared medium, it is necessary to detect instances where two or more stations are transmitting at the same time. This is known as collision detection.

There are two standard types of collision detection, receive and transmit. Both modes compare the average DC voltage on the coaxial cable with respect to ground and determine if a collision is occurring between two transmitting stations.

In ***receive mode collision detection,*** any collision between two separate transmitting nodes will be detected by the transceiver when the average DC cable voltage with two nodes transmitting is from –1.4V to –1.58V. The CY7B8392 and all competition devices have a set internal collision detection voltage that falls into this collision window. IEEE 802.3 standards require receive mode collision detection in applications where repeaters are used. This is done to limit the round trip signal delay to 50 ms, ensuring that all stations on the network will detect a collision before the end of a minimum length packet (57.6 ms). The allowable cable lengths using receive mode collision detection are 185 and 500 meters for 10BASE2 and 10BASE5, respectively.

In ***transmit mode collision detection*** a collision between two stations will be detected while the transceiver is actively transmitting (i.e., it is one of the two colliding stations). Competition 8392 parts require an external voltage divider at the CDS input in order to implement transmit collision detection mode. The voltage divider is used to give the CDS pin a DC offset of approximately –250 mV. Because collision is detected as the voltage difference between the RXI and CDS pins, this allows the coaxial cable to fall 250 mV lower than the receive mode threshold before collision is detected. The relaxed upper limit allows longer cable lengths to be used. Transmit mode collision detection allows 300 and 1000 meters of coaxial cable to be used with 10BASE2 and 10BASE5, respectively.

The collision detection offered only by the CY7B8392 is ***hybrid collision detection,*** a combination of receive and transmit mode collision detection. When the CY7B8392 is not transmitting, it automatically sets the collision threshold voltage to the smaller (less negative) receive level. If the unit enters the transmit mode, the collision detection threshold is automatically changed to the larger (more negative) transmit mode. Hybrid collision detection allows extended cable lengths to be used in non-repeater applications without an external voltage divider at the CDS pin. It can also be used in repeater applications with regular cable lengths without redoing the board design.

In the case of transceivers with receive collision detection, a separate board is required for repeater and long cable applications. Thus, the CY7B8392 Hybrid collision detection is a more flexible solution than the competition's collision detection techniques.

CY7B8392 Heartbeat Function

The CY7B8392 Heartbeat function is enabled when the HBE pin is tied to GND (OV). When enabled, a 10 MHz collision signal is transmitted to the MAC over the CD± pair after the transmission of a packet. For repeater applications the Heartbeat function can be disabled by tying the HBE pin to V_{EE} (–9V). Additionally, if the HBE pin is raised to approximately a TTL level above ground (1.0V nominal) the 8392 enters the test mode state. In the test mode state the Jabber timer, which controls datasheet parameters T_{JA} and $T_{JR,}$ is accelerated by 2^{12}. This allows accelerated testing of these parameters in production.

Designing a 10BASE5 MAU with the CY7B8392

When designing an Ethernet board electrical isolation of both the signal and power supply is necessary. AUI signal isolation is easily achieved through the use of a pulse transformer at the AUI ports. Power isolation is achieved using an isolated DC–DC converter which is required to take the 12V–15V DTE supply as an input and provide a –9V nominal output. To step down the voltage, a transformer is used, which also supplies the required isolation characteristics. For a detailed DC–DC converter design see the section on power supply design in this application note.

Careful consideration should be taken when designing the MAU printed circuit board. According to IEEE 802.3, a total of 4 pF of capacitive loading is allowed for each transceiver attachment in 10BASE5 applications when measured by both a 25 ns rise time and 25 ns fall time waveform (typical coaxial media waveform). This allotment is split into 2 pF of shunt capacitance allowed for the MAU circuitry and 2 pF for the cable tap mechanism. To keep capacitance as low as possible, the traces from TXO and RXI to the connector should be kept as short as possible. The addition of a diode with the anode electrically connected to the TXO port and the cathode to the cable tap mechanism helps minimize tap capacitance by isolating the output capacitance of the export. The CY7B8392 should be directly soldered to the board without a socket to keep stray capacitance to a minimum. Finally, all metal traces, including ground and V_{EE}, should be kept as far from the RXI and TXO traces as possible to minimize stray capacitance. *Figure 7* displays the CY7B8392 layout considerations.

Because 10 BASE5 applications use an AUI drop cable, termination resistors are required on the differential transmit pair. The AUI cable has a characteristic impedance of 78Ω. Using two 39Ω and a 0.01 µF capacitor as the center grounding effectively terminates the line and also minimizes common mode signal, or a more simple 78Ω resistor will suffice.

A controlled breakdown path is required that will shunt high-energy transients to an effective ground. This controlled breakdown is required to meet the isolation requirements out-

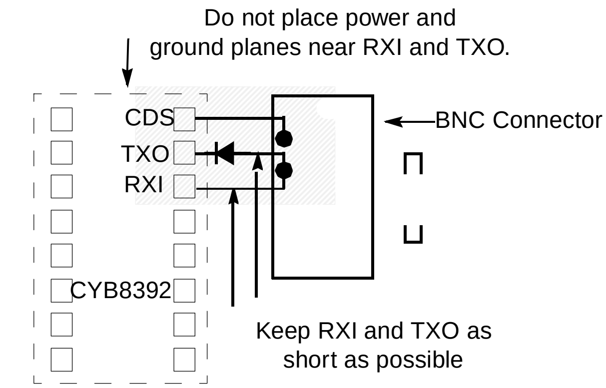

Figure 7. CY7B8392 Application (not to scale)

lined in the IEEE 802.3 standard. In addition, the standard also requires that all applications provide an adequate radio frequency ground return path. These requirements can be met by connecting a 1 MΩ, 0.25Ω resistor and a 0.01 µF capacitor in parallel. The resistor provides the static discharge path while the capacitor ensures low susceptibility to magnetic interference. *Figure 8* shows a typical CY7B8392 10BASE5 application with heartbeat disabled.

Designing a 10BASE2 MAU with the CY7B8392

10BASE2 transceivers are designed using the same circuit as in 10BASE5. The one difference is that an AUI drop cable is not used in 10BASE2. Because an AUI drop cable is not used in Thinnet applications, the termination resistors are not necessary on the incoming TX± signal traces.

Driving Longer Cable with the CY7B8392

With the CY7B8392 it is possible to drive longer cable lengths. Because of the Hybrid collision detection which is available in the CY7B8392, up to 1000m (10 BASE5) or 300m (10 BASE2) of coaxial cable can be used. These extended cable lengths can be used in non-repeater applications only. In repeater applications the standard cable length maximums of 500 and 185 meters must be adhered to. This limit is enforced because the maximum end-to-end delay time for a signal on the network cannot exceed 25 ms by IEEE 802.3 standard. Thus, the total delay of the cable plus a maximum of four repeaters must be less than 25 ms.

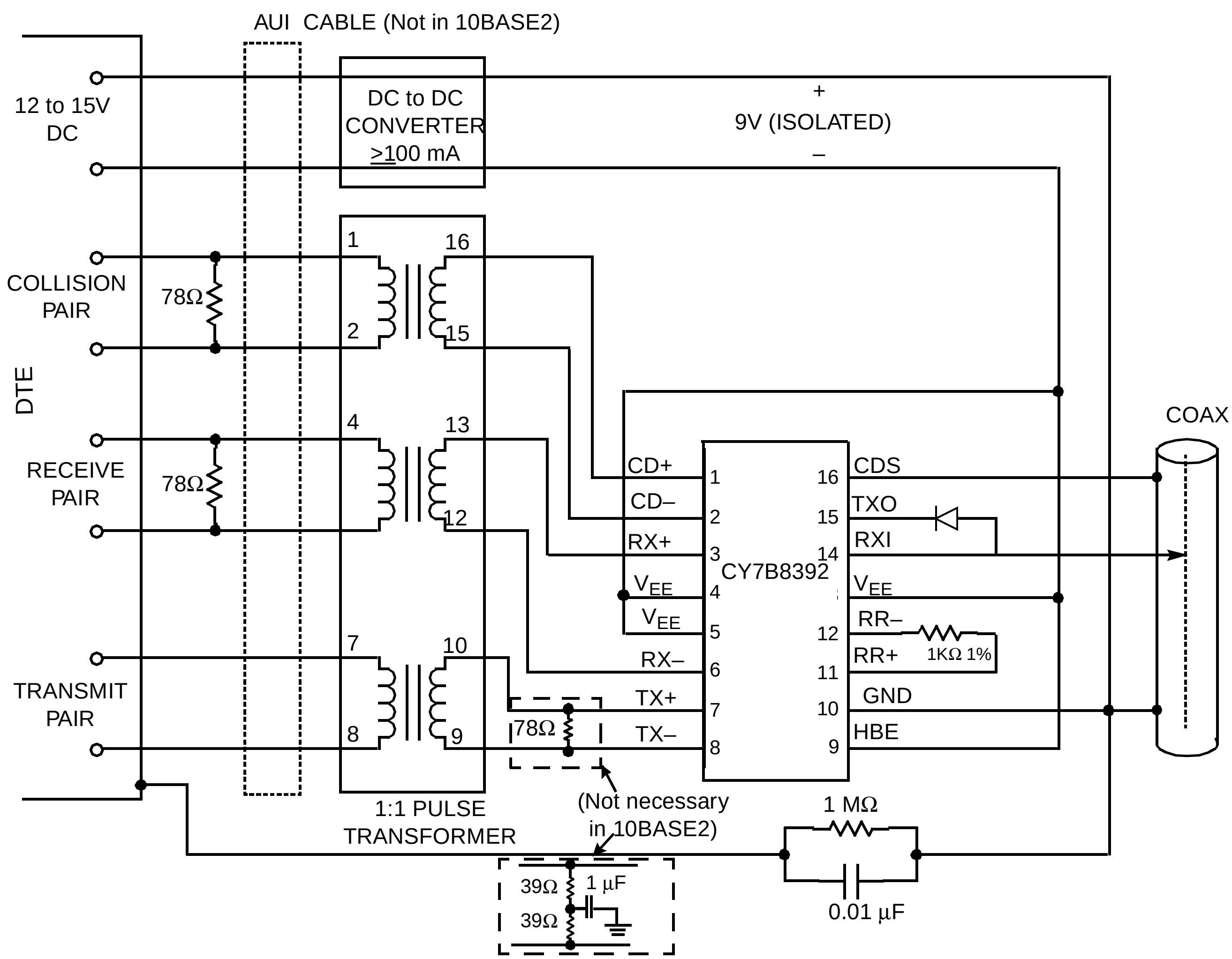

Figure 8. CY7B8392 MAU Application with Heartbeat Disabled[1]

Driving Non-Standard Cable with the CY7B8392

In many situations a network cabling system will already be installed, and some these networks used coaxial cable with different characteristic impedances. Because a significant portion of the cost for installing a LAN is the cost of the cable and the labor to install it, it is in the interest of the customer to use the existing cable plant if possible. This can be achieved either by using a BALUN (BALanced to UNbalanced) or modifying the transceiver board design to operate with the non-standard cable.

Modifying the transceiver board for non-standard cable applications involves attenuating the signal at the RXI and CDS pin. If this is not done then the voltage appearing at the RXI pin will not be within acceptable limits for the CY7B8392. In the case of 93Ω cable, the window for setting collision threshold is between –2637 mV and –2895 mV due to the altered resistance of the cable network. These voltages are calculated by taking the RG-58 A/U thresholds and multiplying by 1.86 (93/50). Because the CY7B8392 is designed to send a collision signal if the DC voltage on the line falls below –1530 mV, every transmission on 93Ω cable will be seen as a collision. Thus, a resistive divider is required to lower the receive voltage to an acceptable level for collision detection. Using standard resistor values, the voltages should be divided so that 1530 mV lies in the acceptable window of collision detection. Choosing a voltage divider with resistor values of 54.9 kΩ and 45.3 kΩ provides a satisfactory result. An example of an application using 93Ω cable is shown in *Figure 9*. The intrinsic capacitance of the RXI pin and trace capacitance (typically 1 pF combined) can create a low pass filter effect with the voltage divider in place. This can be offset by compensated by placing a capacitor (~1.2 pF) in parallel with the leading resistor of the voltage divider, as shown in *Figure 9*. A series 24. 9 kΩ (45.3k||54.9k) resistor is also required on the CDS pin to insure that biasing currents on CDS and RXI produce an equivalent voltage drop.

Any resistor combination that solves *Equation 1* will provide the necessary offset for non-standard cable applications. Larger resistor values are desirable to keep the shunt resistance of the transceiver node as high as possible.

$(R2/R1+R2) *(Z_{COAX} /50\Omega)=1$ Eq. 1

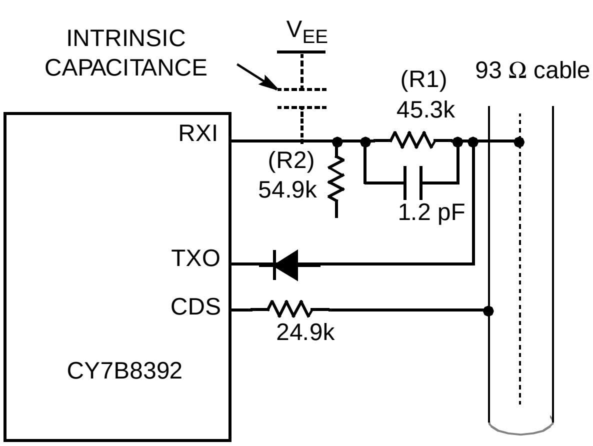

Figure 9. CY7B8392 Application using 93Ω Cable

(Z_{COAX}=Non-standard cable impedance)

When different resistor values are used at the voltage divider of RXI, the biasing resistor at CDS must also be changed to reflect the altered parallel resistance of R1 and R2.

Auto-AUI Function

The CY7B8392 Auto-AUI function allows a 10BASE designer the ability to easily design NICs (Network Interface Cards). The Auto-AUI function has the ability to switch between AUI, twisted pair, and coax connections (assuming both the twisted pair and coax transceivers have Auto-AUI function). This feature benefits both the board designer with a cost savings, and the user who no longer has to open the computer or program software to reconfigure the NIC.

A typical NIC is shown in *Figure 10*. If the user wishes to change from the AUI port to the 10BASE2 coaxial connection it is necessary to open the computer and flip switches, or in some cases reconfigure the NIC software through a tedious process. Both of these situations require the user to consult a manual for reference. If this manual is lost, changing the configuration becomes problematic for the user.

Figure 11 shows a NIC design using the CY7B8392 Auto-AUI function. This application eliminates the need for switches/jumpers or special software. The CY7B8392 automatically does the reconfiguration by either turning its AUI drivers on (properly terminated coaxial cable is attached), or placing them in a high-impedance state (no coaxial cable attached). Thus, simply attaching a coaxial cable to the 10BASE2 coaxial port and leaving the 10BASE–T and AUI ports unconnected automatically configures the NIC.

DC–DC Converter Design for CY7B8392 Applications

In MAU applications the CY7B8392 requires a –9V isolated power supply from a 12–15V power source. Both discrete and integrated DC–DC converters are available for this application. Integrated DC–DC converters are available through several vendors (Fil–Mag, Valor). A discrete design can be provided through a transformer, self-oscillating primary, and rectifying secondary. Because the 8392 consumes very little power when compared to competitive devices a discrete transformer allows the designer to minimize the DC–DC cost through the selection of low power components. A schematic of the circuit is shown in *Figure 12*.

The function of the circuit is as follows: Initially, 12V is applied across the input of the converter. This causes the voltage at (1) to rise until one of the transistors arbitrarily turns on. For this example we will assume that Q1 turns on. As Q1 starts conducting, current begins to flow through the transformer winding connected to the collector of Q1. This current change is opposed by the inductive characteristics of the transformer, which induces a voltage in the opposite direction. Because all the transformer windings are wound around a common core, every separate winding will induce a voltage. The direction of the induced voltages follow the transformer dot convention. Thus, with Q1 ramping, every winding appears as a voltage source with the positive terminal at the end of the winding (opposite the dot). This induced voltage will force the base voltage of Q1 higher, turning it on hard, and force the base voltage of Q2 low, ensuring that it remains off.

At the same time the current is ramping up in the primary, the voltage induced in the transformer is applied to the secondary

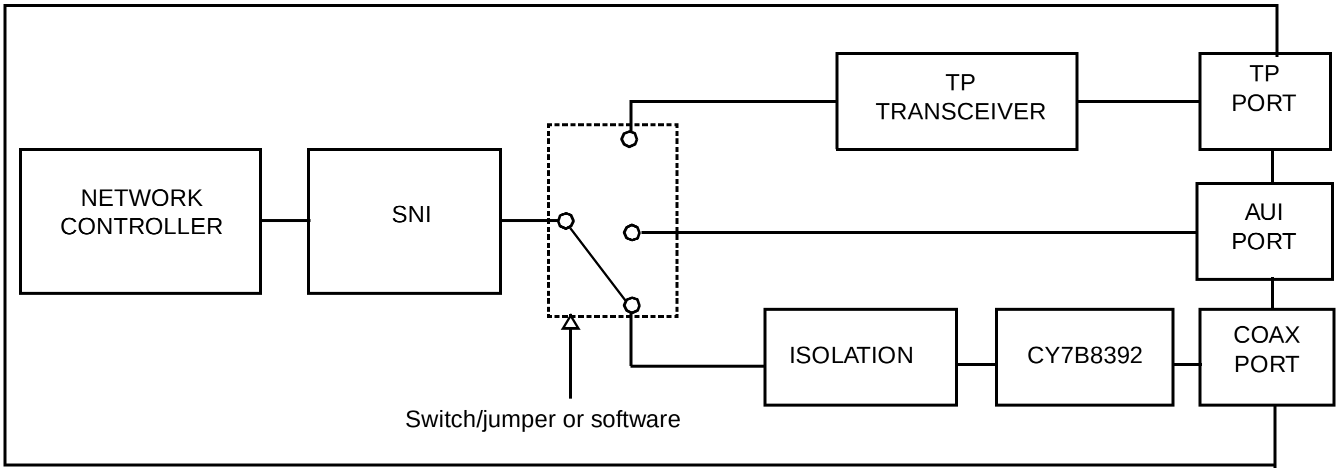

Figure 10. Typical Network Interface Card

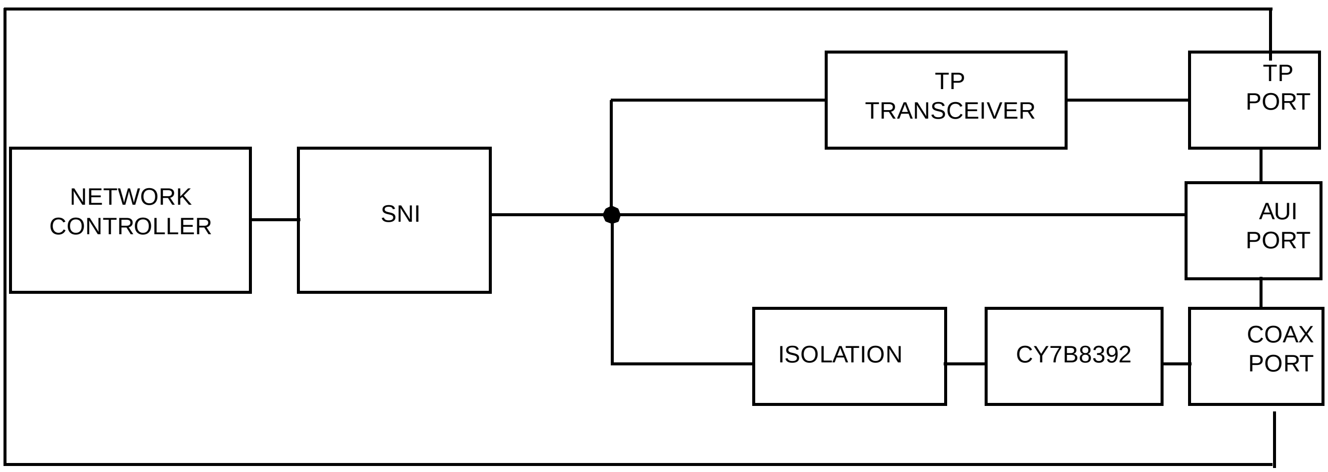

Figure 11. Advanced Network Interface Card with Auto-AUI Function

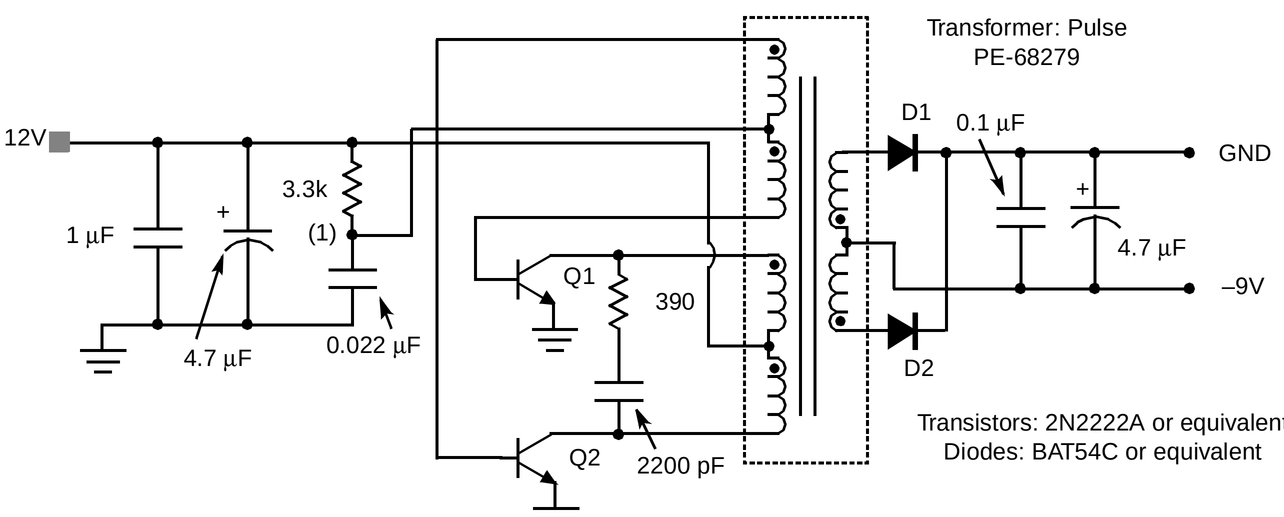

Figure 12. DC–DC Converter Design

rectification circuit. Again, following the dot convention, a positive voltage is applied at the cathode of D1 and a negative voltage at the cathode of D2. Current flows through D1 and charges the output capacitors, while D2 opposes current flow.

Eventually, as the current increases in Q1, it reaches a point where the 12V supply cannot continue to sustain di/dt. As this occurs, the induced voltage opposing the current flow in the transformer will disappear. Consequently, the voltage at the base of Q1 will be unable to sustain the collector current and Q1 will come out of saturation. In turn, the current flow in the winding will begin to decrease. Because the inductive nature of the transformer opposes the change in current, a voltage is induced which opposes this decrease in current. Following the dot convention, the positive terminal appears at the beginning of the winding (the end with the dot). The induced voltage forces the voltage at the base of Q2 high and turns the transistor on hard while Q1 is forced off. The current then flows through the transformer winding to the collector of Q2 and then to ground. In this manner the primary circuit oscillates and changes DC to AC.

Applying the induced voltage to the secondary rectification circuit, a positive voltage is applied to the cathode of D2, which allows current to charge the output capacitors. These capacitors minimize voltage ripple at the output and provide a constant DC supply to the CY7B8392.

If the CY7B8392 is being used in an adapter card application where 5V± 5% is available, then the discrete DC–DC converter shown in *Figure 12* can be easily redesigned to use this supply. Simply replace the 3.3 KΩ resistor on the input with a 270Ω resistor and change the transformer to a Pulse PE–68283.

CY7B8392 vs. The Competition

As shown in this application note and the CY7B8392 data sheet, the Cypress coaxial transceiver has features which set it apart from the competition. The low power characteristics of the CY7B8392 mean that the cost of the power supply is reduced, saving on the overall cost of the board design. Cypress hybrid collision detection, available only on the CY7B8392, allows larger diameter networks to be used without reconfiguring the transceiver board with a voltage divider at CDS. Pull-down resistors are no longer required on the RX± and CD± AUI ports, again minimizing board space and cost. These features make the CY7B8392 a standard to follow in coaxial Ethernet transceiver applications.

Note:

1. The TX± 78Ω termination resistor may be exchanged with two 39Ω resistors and a 1-µF capacitor for common mode rejection. Only one configuration should be used, not both together.