General Description

It is a common practice to capacitively couple Ethernet transceivers (PHYs) together without the use of a transformer to reduce both the BOM cost and PCB area. This application note describes methods for capacitive coupling of Micrel's 10/100 Ethernet devices.

Micrel Devices for Capacitive Coupling

- **KS8695X**  CENTAUR – Integrated Multi-port Gateway Solution
- **KS8695P/PX**  CENTAUR – Integrated Multi-port PCI Gateway Solution
- **KS8721B/BT**  Single Port 10/100 PHY with Auto MDI/MDI-X Crossover
- **KS8721BL/SL**  3.3V Single Power Supply 10/100 PHY with Auto MDI/MDI-X Crossover
- **KS8993** 3-Port 10/100 Unmanaged Switch
- **KS8993F** 3-Port 10/100 Managed/Unmanaged Switch/Media Converter with TS-1000 OAM
- **KS8993M** 3-Port 10/100 Managed/Unmanaged Switch
- **KS8995M/X** 5-Port 10/100 Managed/Unmanaged Switch
- **KS8995MA/XA** 5-Port 10/100 Managed/Unmanaged Switch
- **KS8997** 8-Port 10/100 Unmanaged Switch
- **KS8999** 9-Port 10/100 Unmanaged Switch

Methods for Capacitive Coupling

The method for capacitive coupling depends upon whether or not the receiver circuit provides an internal DC bias offset.

Transmit Termination

Figures 1 and 2 show the capacitive coupling for transmit-side termination. In this method, the 50Ω pull-up resistors R1 and R2 are pulled up to analog VDD. All Micrel devices listed in this application note require this output termination, except for the KS8993 device.

For the KS8993, R1 and R2 are tied together, but not to VDD. The TXPx and TXMx differential signals are each terminated with 50Ω pull-ups to the port's VREFx pin.

Receive Termination for Devices with Internal DC Bias

Figure 1 shows the circuit diagram for capacitive coupling to a receiver with internal DC biasing. The 50Ω pull-up resistors R1 and R4 on the receiver inputs provide the necessary DC offset. These 50Ω resistors also provide the input termination.

This method is applicable to the KS8695X, KS8695P/PX, KS8721B/BT, KS8721BL/SL, KS8993M/F, KS8995M/X, and KS8995MA/XA, none of which provide internal DC biasing.

Transmit /Receive Termination for KS8997 and KS8999

Figure 2 shows the capacitive coupling between two KS8997 or KS8999 devices. It is necessary to choose pull up resistor values (R1, R2, R3, and R4) that will provide the DC offset for the transmit differential pair Txdc level greater than 1.3V in order to maintain a reasonable and balanced swing. To accomplish this, the following values should be utilized:

- VDD = 2.1V (typ)
- R1, R2, R3, R4 = 33 ohms
- Txdc = 1.44V (VDD-20mA x 33ohms)
- Swing = +/- 330mV (20mA x 33/2 ohms)

or
VDD = 2.3V(max)
R1, R2, R3, R4 = 40 ohms
Txdc = 1.5V (VDD-20mA x 40ohms)
Swing = +/- 400mV (20mA x 40/2 ohms)

Using these values will provide a reliable capacitively coupled circuit between two KS8997 or KS8999 devices over a short distance.

**Recommended Link Configuration**

Configure both link partners as follows:
- Force Mode (auto-negotiation disabled)
- Auto MDI/MDI-X (disabled)
- 100BASE-TX

The only exception to this recommendation is the KS8997. The KS8997 does not support force mode and auto-negotiation must be performed. Auto-negotiation has been verified under these circumstances.

The designer can choose either half-duplex or full-duplex mode.

**100BASE-TX Applications**

For 100BASE-TX, the transmit drivers are current-driven for all the Micrel devices discussed in this application note.

The transmit side drives at 20mA single-ended. If the supply voltage for the 100BASE-TX transmitters and the transmit side pull-up resistors (R1, R2) is 2.5V, the DC offset for the transmit differential pair is 1.5V (2.5V - (0.02A x 50Ω) = 1.5V).

On the receive side, the receive differential pair has a very high input impedance. If the supply voltage for the 100BASE-TX receivers and receive-side pull-up resistors (R3, R4) is 2.5V, the DC offset for the receive differential pair will still be approximately 2.5V.

**10BASE-T Applications**

If 10BASE-T configuration is required, the given methods for capacitive coupling are valid only if the 10BASE-T transmitter circuit design is voltage driven. The KS8695X, KS8695P/PX, KS8993, KS8993M/F, and KS8995MA/XA all have voltage drive 10BASE-T transmitter circuitry.

When using the standard 50Ω termination, current drive 10BASE-T transmitters are unable to provide a full 2.3V output amplitude swing. For example, with a 50mA output drive and two 50Ω pull-up resistors (R1, R2), the voltage drop is 2.5V (0.05A x 50Ω = 2.5V); thus, the signal is fully attenuated. To increase the output voltage swing at the receiver, it is recommended to implement the following resistor changes:

- R1, R2 = 15Ω
- R3, R4 = 75Ω

Using this method provides a voltage swing greater than the minimum 400mV receiver squelch threshold. The consequence of altering the pull-up resistor values to provide a minimum output voltage swing is a slight mismatch in the termination impedance. Signal traces should be kept to a minimum length to avoid poor signal integrity. The KS8721B/BT, KS8721BL/SL, KS8995M/X, KS8997, and KS8999 all have current drive 10BASE-T transmitter circuitry.

For additional information, contact your local Micrel Field Application Engineer or salesperson.