Capacitive Coupling Ethernet Transceivers without Using Transformers

Introduction

It is a common practice to capacitive 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.

External Termination Ethernet Devices

The Ethernet devices in Table 1 require external termination resistors. They require external biasing or internal biasing.

Table 1. Micrel Devices with External Termination

External Biasing and External Termination Ethernet Device	
KSZ8695 Family	CENTAUR – SoC
KSZ8721 Family	Single Port 10/100 PHY
KSZ8001 Family	Single Port 10/100 PHY
KSZ8041 Family	Single Port 10/100 PHY
KSZ8841 Family	Single Port 10/100 MAC Controller
KSZ8842 Family	2-Port 10/100 Switch
KSZ8893 Family	3-Port 10/100 Switch
KSZ8873 Family	3-Port 10/100 Switch
KSZ8863 Family	3-Port 10/100 Switch
KSZ8851 Family	Single Port 10/100 MAC Controller
KSZ8995 Family	5-Port 10/100 Switch
KSZ8997	8-Port 10/100 Unmanaged Switch
KSZ8999	9-Port 10/100 Unmanaged Switch
Internal Biasing and external termination Ethernet Device	
KSZ8993 family	3-Port 10/100 Switch

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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

Figure 1 and Figure 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 3.3V VDD (with the exception that KSZ8999/7 is 2.1V). All Micrel external termination resistors devices listed in Table 1 require this output termination, except for the KSZ8993 device.

For KSZ8993, the R1 and R2 resistors are tied together, but not connected to VDD. The TXPx and TXMx differential signals are each terminated with 50Ω pull-ups to the port's analog power.

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 R3 and R4 are capacitive coupled via C3 to analog 3.3V V_{DD}, providing the correct receiver input termination. This method is applicable to the KSZ8993, which provides internal DC biasing.

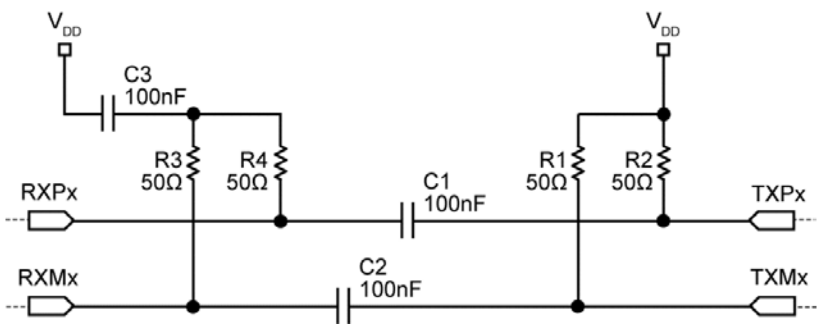

Figure 1. Capacitive Coupling Circuit Diagram for Receivers with Internal DC Bias

Receive Termination for Devices without Internal DC Bias

Figure 2 shows the circuit diagram for capacitive coupling to a receiver without internal DC biasing. In this illustration, the 50Ω pull-up resistors R3 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 KSZ8695 family, KSZ8721 family, KSZ8001 family, KSZ8041 family, KSZ8841 family, KSZ8842 family, KSZ8893 family, KSZ8993M/F family, KSZ8873/8863 family, KSZ8995 family and KSZ8851 family, none of which provide internal DC biasing.

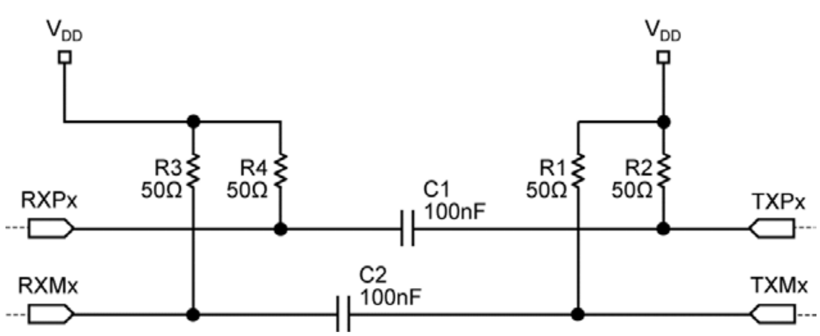

Figure 2. Capacitive Coupling Circuit Diagram for Receivers without Internal DC Bias

Transmit /Receive Termination for KSZ8997 and KSZ8999

Figure 2 shows the capacitive coupling between two KSZ8997 or KSZ8999 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 = 33Ω

Txdc = 1.44V (VDD-20mA x 33Ω)

Swing = ±330mV (20mA x 33/2Ω)

or

VDD = 2.3V(max)

R1, R2, R3, R4 = 40Ω

Txdc = 1.5V (VDD-20mA x 40Ω)

Swing = ±400mV (20mA x 40/2Ω)

Using these values will provide a reliable capacitive coupled circuit between two KSZ8997 or KSZ8999 devices over a short distance.

Recommended Link Configuration

Configure both link partners as follows:

Force - Force mode (both auto-negotiation disabled with same speed and duplex mode), faster link-up time.

Force MDI/MDI-X mode (disabled, MDI-MDI or MDIX-MDIX), faster link-up time.

AN - AN mode (both Auto-Negotiation enabled).

Auto-MDI/MDIX mode (enabled).

100BASE-TX speed mode.

The only exception to this recommendation is the KSZ8997. The KSZ8997 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 3.3V, the DC offset for the transmit differential pair is 2.3V (3.3V - (0.02A x 50Ω) = 2.3V).

On the receive side, the receiving 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 3.3V, the DC offset for the receiving differential pair will still be approximately 3.3V.

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 KSZ8695 family, KSZ8001 family, KSZ8041 family, KSZ8841 family, KSZ8842 family, KSZ8993 family, KSZ8893 family, KSZ8873 family, KSZ8851 family and KSZ8995MA/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 KSZ8721 family, KSZ8995M/X, KSZ8997, and KSZ8999 all have current drive 10BASE-T transmitter circuitry.

Internal Termination Ethernet Devices

These Ethernet devices in Table 2 are internal on-chip termination and internal DC biasing.

Table 2. Micrel Devices with Internal Termination/Biasing

Internal Biasing and Internal On-chip Termination Device	
KSZ8051 Family	Single Port 10/100 PHY
KSZ8081 Family	Single Port 10/100 PHY
KSZ8091 Family	Single Port 10/100 PHY
KSZ8895 Family	5-Port 10/100 Switch
KSZ8864 Family	4-Port 10/100 Switch
KSZ8463	3-Port 10/100 Switch
KSZ8462	2-Port 10/100 Switch
KSZ8852	2-Port 10/100 Switch
KSZ8795	5-Port 10/100 Switch
KSZ8775	5-Port 10/100 Switch
KSZ8765	5-Port 10/100 Switch
KSZ8794	4-Port 10/100 Switch
KSZ8061	Single Port 10/100 PHY

Methods for Capacitive Coupling

The method for capacitive coupling depends upon whether the device provides an internal DC bias offset.

Connection between Two Internal On-chip Termination and Internal DC Biasing Devices

Figure 3 show the capacitive coupling between two internal on-chip termination and internal biasing devices.

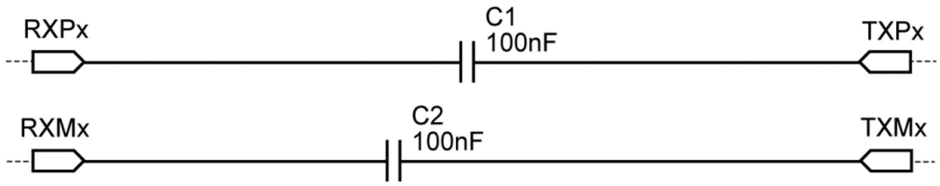

Figure 3. Capacitive Coupling Circuit Diagram for Two Internal Termination/Biasing Devices

Connection between Internal Termination/Biasing and External Termination/Biasing Devices

Figure 4 shows the circuit diagram for capacitive coupling between internal termination/biasing and external termination/biasing devices.

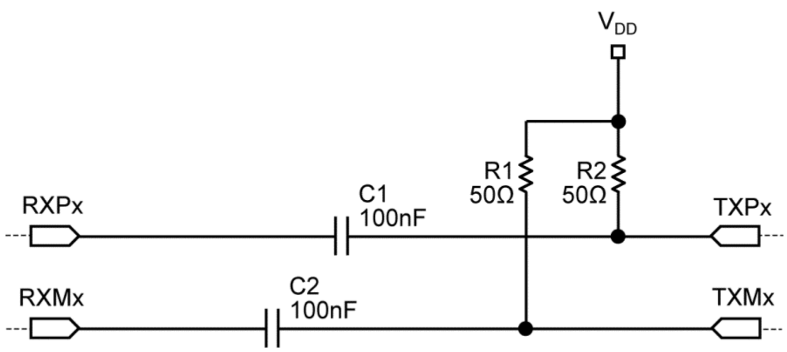

Figure 4. Capacitive Coupling Circuit Diagram for Receivers with an Internal Termination/Biasing and Transmit with an External Termination/Bias Devices

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

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