Transmission Distance and Jitter Guide

IDT77V1264L200
Application Note
AN-330

Notes

Revision History

September 27, 2001: Initial publication.

Cable Length Guide for the 77V1264L200

Overview

The purpose of this document is to demonstrate the signal quality of TX and RX signals over 10m of UTP5 cable when using the IDT77v1264L200 ATM PHY. For comparison purposes, results of some simulations done with 10m of RG174 coax cable are also shown. Signal quality simulations for 1.5m of traces on an FR4 material PCB, including connectors, are shown for backplane applications.

Test Results

Several tests were run over 10m of UTP5 cable where one port of the 77v1264L200 transmitted or received data to / from another 77v1264L200 ATM PHY. The BER test was run for extended periods of times (up to 72 hours). No Bit errors were seen and the signals showed a clean open eye diagram.

Simulations were done for RG174 cable and showed clean eye opening waveforms. Simulations for backplane applications, where signals are expected to run through approximately 1.5 meters of trace length and through connectors, also showed clean eye opening waveforms.

Bit Error Rate Test

These tests were performed to verify that no bit errors are seen for all line rates that the IDT77V1264L200 ATM PHY is recommended for. At the time this document is written, the ATM forum specifies that BER should not exceed 1E-10 at data rates of 25.6Mbps. There is no specification for higher data rates.

Test Set-up

An ATM generator / analyzer (Adtech) was used as the data source. The maximum data output of this generator is limited to 150Mbps. The data rate was adjusted based on the multiplier set in the Enhanced control register 2 of the IDT77V1264L200. In order to separate the data between different ports of the PHY, different VCIs were sent to each port.

Two SwitchStar motherboards were used — each with a separate 77v1264L200 line card.

DSC 6055

Notes

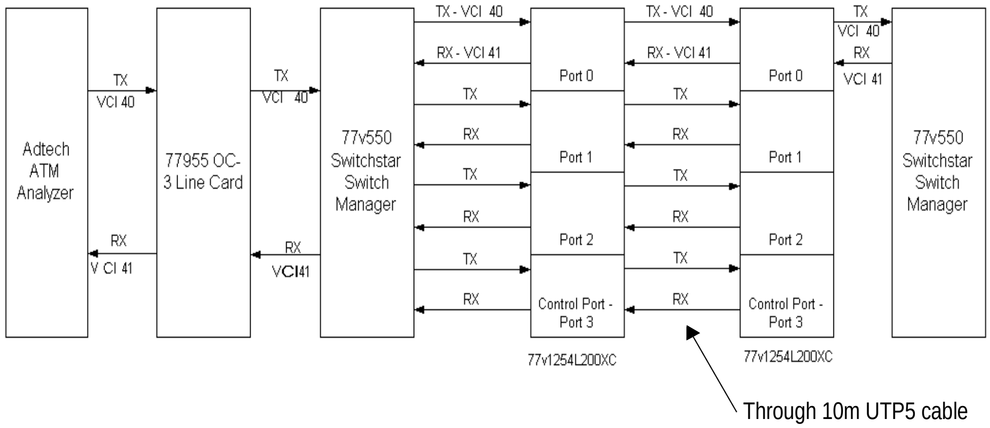


Figure 1 Configuration for Bit Error rate tests

In the above configuration, only one port was active when the line rate was 256Mbps. For 32Mbps and 64Mbps, more than one port was active. Using the same configuration, different lengths of UTP5 cable ranging from 1m to 10m were used. Refer to signal quality and jitter measured in the next section.

Bit Error Rate Test Results

The 256Mbps bit error test was run for 72 hours. All other tests were run for more than 24 hours. No errors were seen in any of these tests, and all data transmitted was properly received. The test configuration for these tests is shown in Figure 1.

Jitter and Signal Integrity Tests

This test was done to ensure that the signal quality is acceptable when data is sent or received over 10m of UTP5 cable. This test was run with all line rates that the IDT77V1264L200 ATM PHY can operate with. Both Phys have fixed but separate oscillators (FOX 1100E).

Test Set-up

The test configuration used was same as shown in Figure 1. The UTP5 cable connecting one system to another was changed for different lengths.

Cable Length	Oscillator	Multiplier	Line Rate	Jitter	Jitter Spec Limit 4ns - Pass / Fail	Bit error rate limit 1E-10 - Pass / Fail
10m	32Mhz	1x	32Mbps	1.2ns	Pass	Pass
10m	32Mhz	2x	64Mbps	1.32ns	Pass	Pass
10m	32Mhz	4x	128Mbps	920ps	Pass	Pass
10m	64Mhz	1x	64Mbps	1.2ns	Pass	Pass
10m	64Mhz	2x	128Mbps	1.04ns	Pass	Pass
10m	64Mhz	4x	256Mbps	680ps	Pass	Pass
9m	32Mhz	1x	32Mbps	1ns	Pass	Pass
9m	32Mhz	2x	64Mbps	1.2ns	Pass	Pass

Notes

Cable Length	Oscillator	Multi-plier	Line Rate	Jitter	Jitter Spec Limit 4ns - Pass / Fail	Bit error rate limit 1E-10 - Pass / Fail
9m	32Mhz	4x	128Mbps	880ps	Pass	Pass
9m	64Mhz	1x	64Mbps	1.1ns	Pass	Pass
9m	64Mhz	2x	128Mbps	1.04ns	Pass	Pass
9m	64Mhz	4x	256Mbps	640ps	Pass	Pass
8m	32Mhz	1x	32Mbps	1.2ns	Pass	Pass
8m	32Mhz	2x	64Mbps	1.2ns	Pass	Pass
8m	32Mhz	4x	128Mbps	840ps	Pass	Pass
8m	64Mhz	1x	64Mbps	1.2ns	Pass	Pass
8m	64Mhz	2x	128Mbps	1.0ns	Pass	Pass
8m	64Mhz	4x	256Mbps	560ps	Pass	Pass
6m	32Mhz	1x	32Mbps	1ns	Pass	Pass
6m	32Mhz	2x	64Mbps	1.2ns	Pass	Pass
6m	32Mhz	4x	128Mbps	800ps	Pass	Pass
6m	64Mhz	1x	64Mbps	1.2ns	Pass	Pass
6m	64Mhz	2x	128Mbps	1ns	Pass	Pass
6m	64Mhz	4x	256Mbps	560ps	Pass	Pass
4m	32Mhz	1x	32Mbps	1ns	Pass	Pass
4m	32Mhz	2x	64Mbps	1.2ns	Pass	Pass
4m	32Mhz	4x	128Mbps	840ps	Pass	Pass
4m	64Mhz	1x	64Mbps	1ns	Pass	Pass
4m	64Mhz	2x	128Mbps	1.08ns	Pass	Pass
4m	64Mhz	4x	256Mbps	640ps	Pass	Pass
2m	32Mhz	1x	32Mbps	1ns	Pass	Pass
2m	32Mhz	2x	64Mbps	1ns	Pass	Pass
2m	32Mhz	4x	128Mbps	760ps	Pass	Pass
2m	64Mhz	1x	64Mbps	1ns	Pass	Pass
2m	64Mhz	2x	128Mbps	1.08ns	Pass	Pass
2m	64Mhz	4x	256Mbps	600ps	Pass	Pass
1m	32Mhz	1x	32Mbps	1ns	Pass	Pass
1m	32Mhz	2x	64Mbps	1.1ns	Pass	Pass
1m	32Mhz	4x	128Mbps	800ps	Pass	Pass
1m	64Mhz	1x	64Mbps	1ns	Pass	Pass

Notes

Cable Length	Oscillator	Multiplier	Line Rate	Jitter	Jitter Spec Limit 4ns - Pass / Fail	Bit error rate limit 1E-10 - Pass / Fail
1m	64Mhz	2x	128Mbps	920ps	Pass	Pass
1m	64Mhz	4x	256Mbps	600ps	Pass	Pass

Jitter Test Results

The table above shows jitter measured when using different lengths of UTP5 cable. Triggering at the oscillator, jitter was measured at the end of the UTP5 cable using infinite persistence on a high-speed oscilloscope.

Although there is no specification available at this time for higher data rates, the ATM forum defines a 4ns maximum jitter at 25.6Mbps data rate. This standard was used to determine if the PHY passed or failed to meet the spec. Jitter at all data rates was less than 4ns.

Signal Integrity Tests Results

The purpose of this test was to measure the jitter at the end of different lengths of UTP5 cable. Data was sent back from the receiving end to the ATM data generator to verify that there are no errors seen. Waveforms were captured at all data rates to ensure that there is no significant noise or jitter when using the ST6200T magnetics from Pulse Engineering. Waveforms for some of the jitter data collected are shown below.

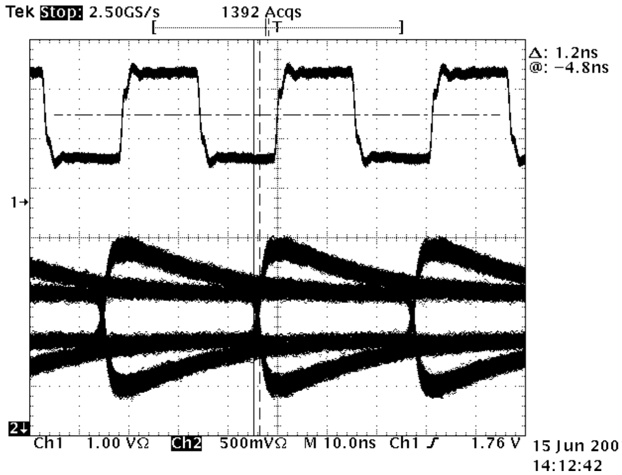
Notes

Waveforms With 10m UTP5 Interface Cable

Waveform at 32 Mbps line rate, 10m cable.

Waveform at 32MHz OSC.

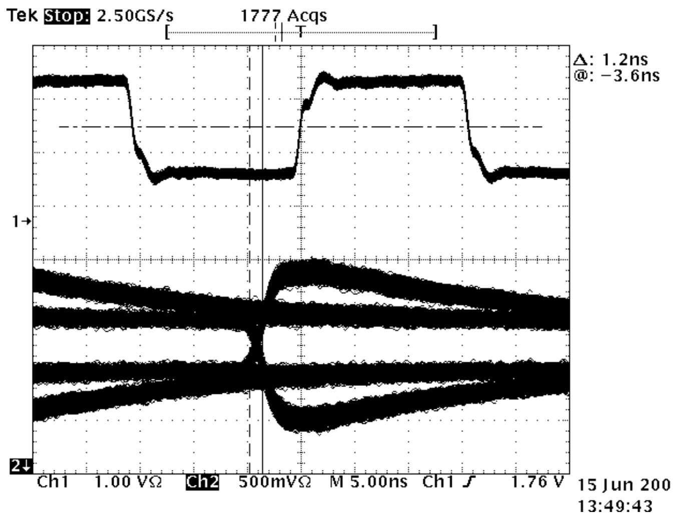
Waveform at RX pin after 10m cable.



Jitter at 32 Mbps line rate, 10m cable.

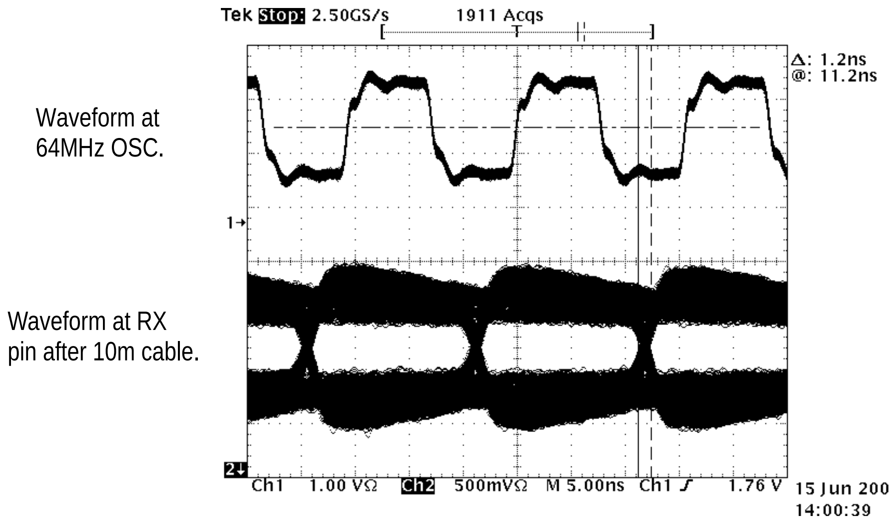
Waveform at 32MHz OSC.

Waveform at RX pin after 10m cable.

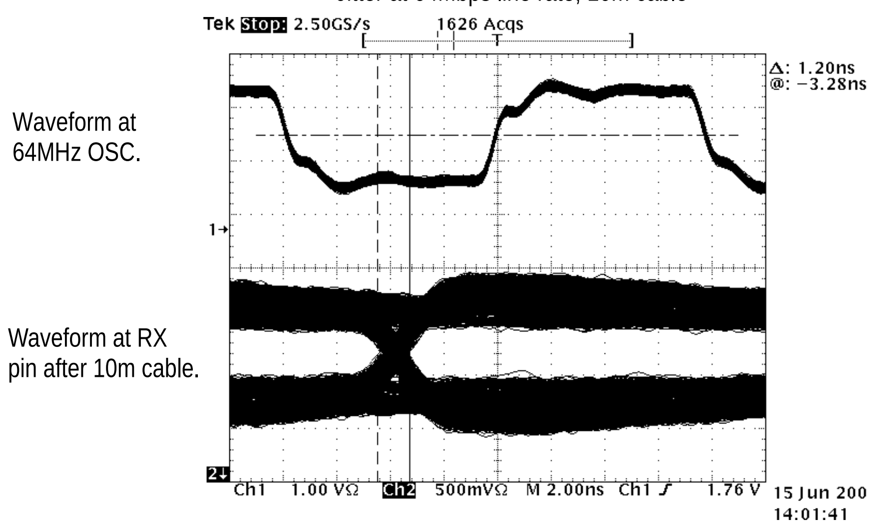


Notes

Waveform at 64Mbps line rate, 10m cable.



Jitter at 64Mbps line rate, 10m cable

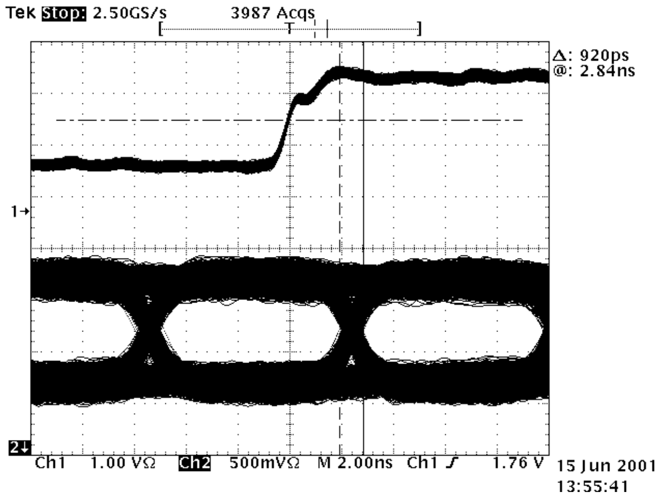


Notes

Waveform at 128Mbps line rate, 10m cable.

Waveform at 64MHz OSC.

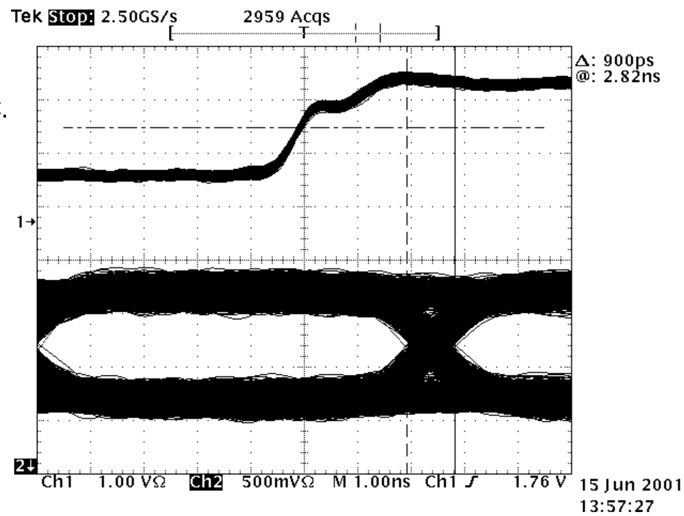
Waveform at RX pin after 10m cable.



Jitter at 128Mbps line rate, 10m cable.

Waveform at 64MHz OSC.

Waveform at RX pin after 10m cable.

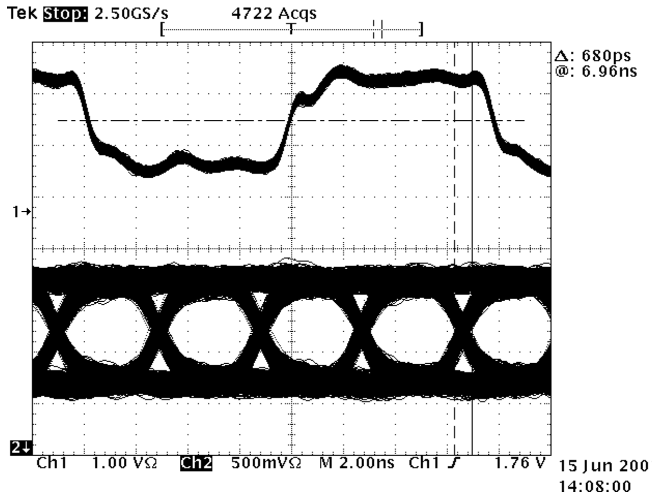


Notes

Waveform at 256Mbps line rate, 10m cable.

Waveform at 64MHz OSC.

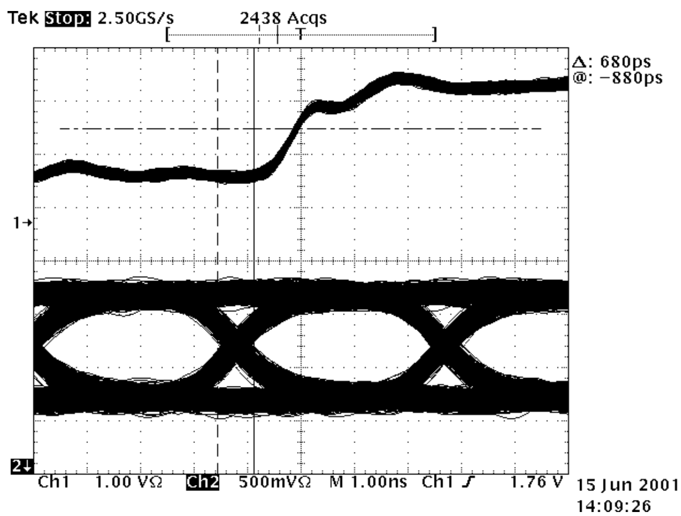
Waveform at RX pin
after 10m cable



Jitter at 256Mbps line rate, 10m cable.

Waveform at 64MHz OSC.

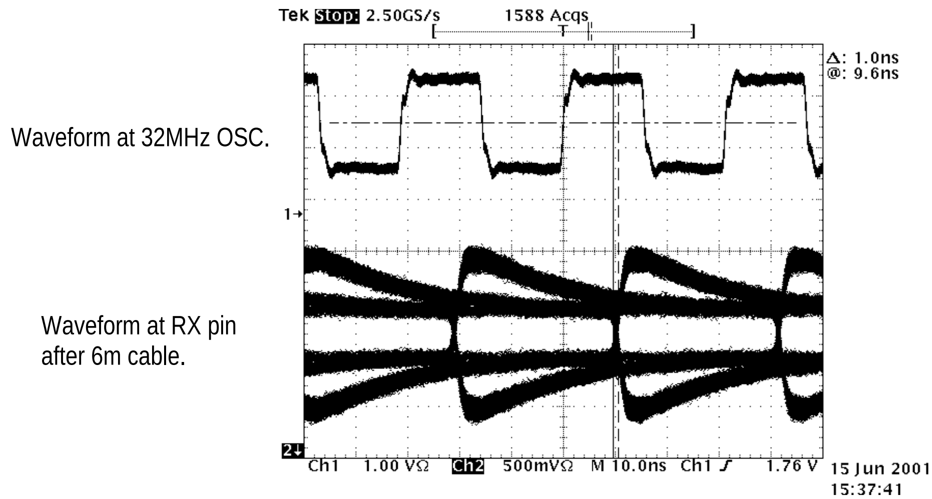
Waveform at RX pin
after 10m cable



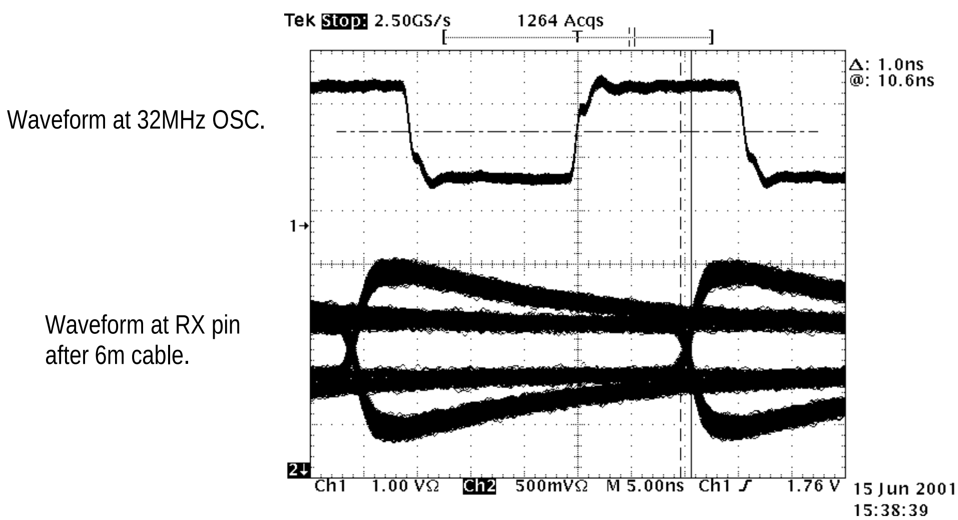
Notes

Waveforms With 6m UTP5 Interface Cable

Waveform at 32Mbps line rate, 6m cable.

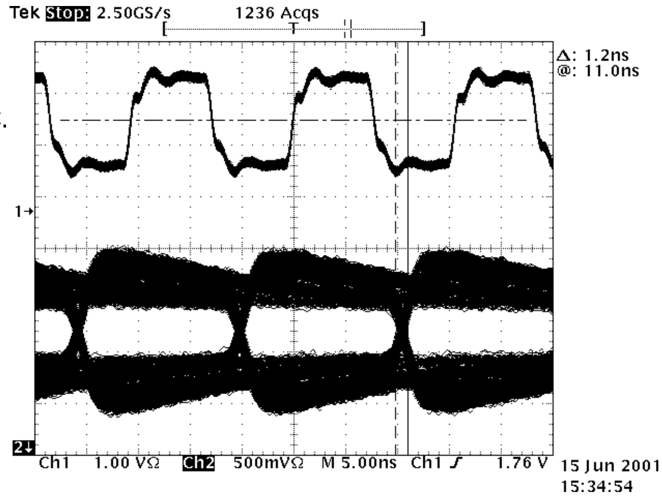


Jitter at 32Mbps line rate, 6m cable



Notes

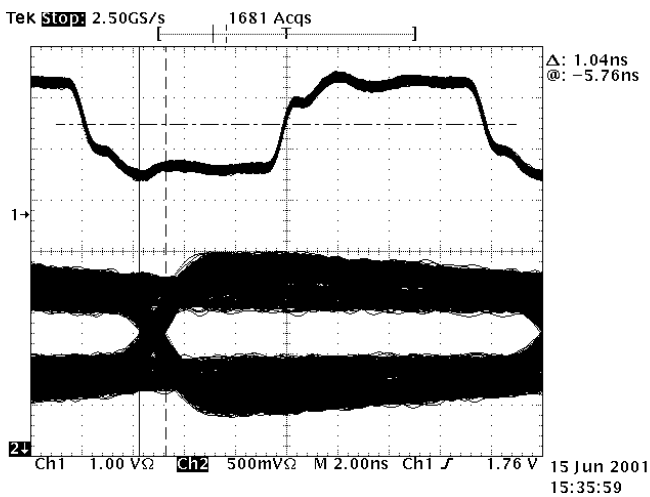
Waveform at 64Mbps line rate, 6m cable.



Waveform at 64MHz OSC.

Waveform at RX pin after 6m cable.

Jitter at 64Mbps line rate, 6m cable.



Waveform at 64MHz OSC.

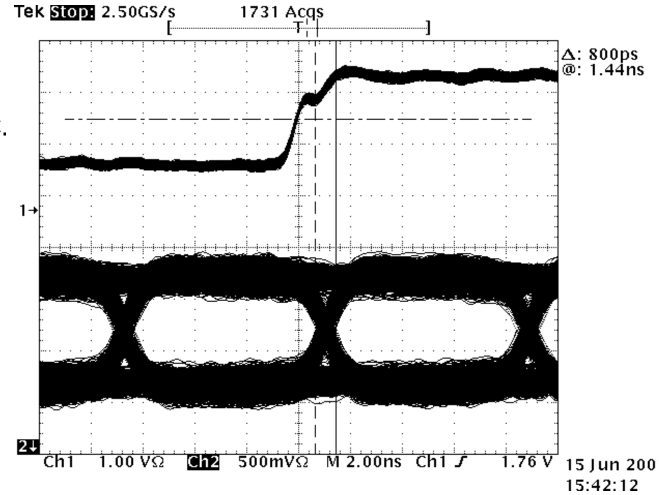
Waveform at RX pin after 6m cable.

Notes

Waveform at 128Mbps line rate, 6m cable.

Waveform at 64MHz OSC.

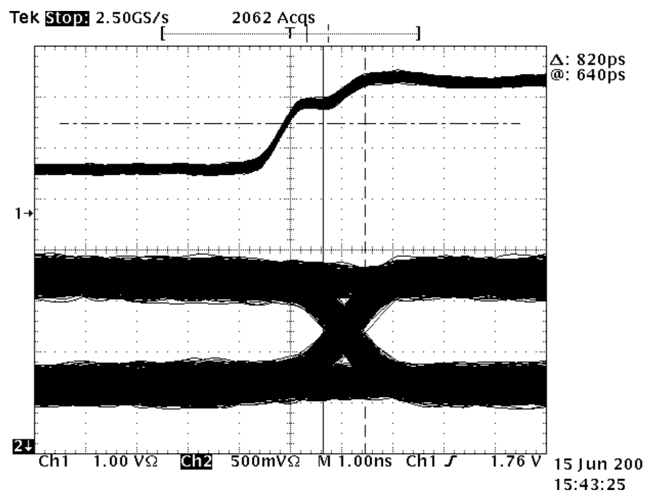
Waveform at RX pin after 6m cable.



Jitter at 128Mbps line rate, 6m cable.

Waveform at 64MHz OSC.

Waveform at RX pin after 6m cable.

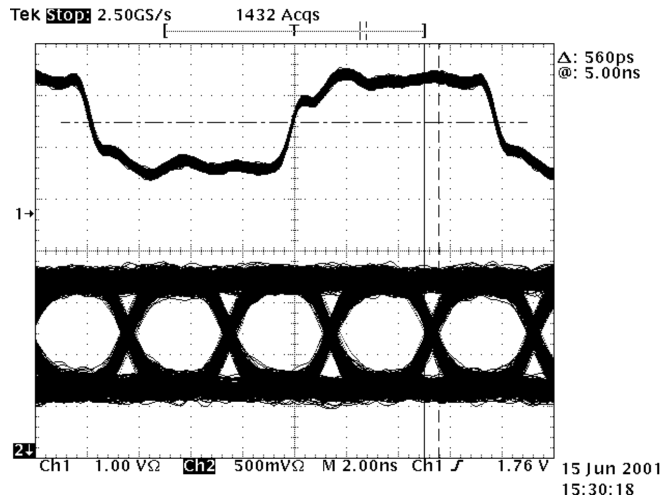


Notes

Waveform at 256Mbps line rate, 6m cable.

Waveform at 64MHz OSC.

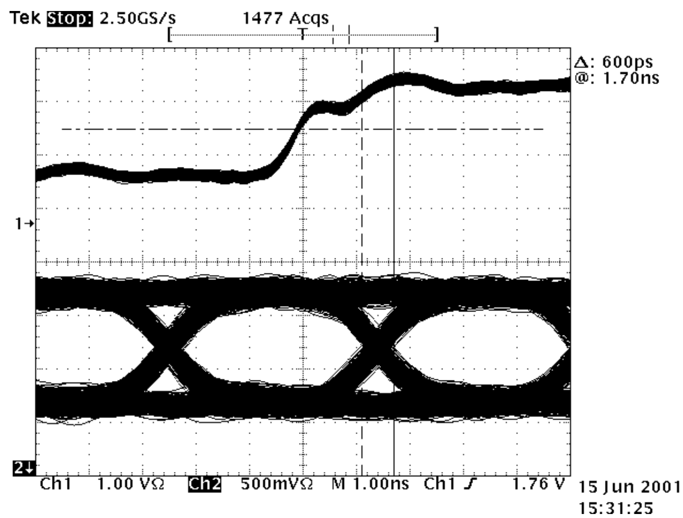
Waveform at RX pin after 6m cable.



Jitter at 256Mbps line rate, 6m cable.

Waveform at 64MHz OSC.

Waveform at RX pin after 6m cable.



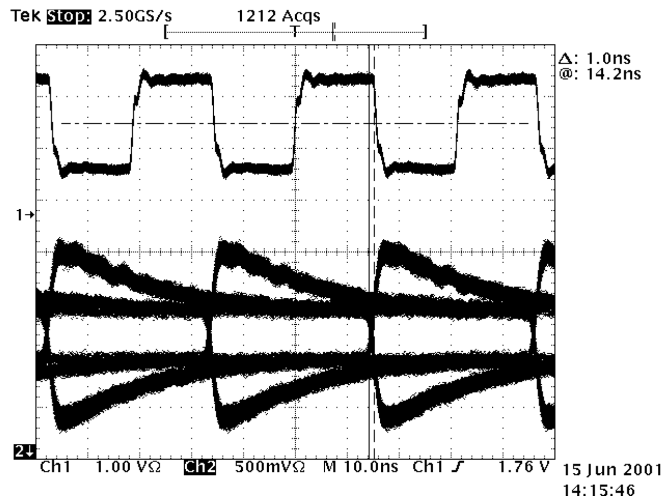
Notes

Waveforms With 1m UTP5 Interface Cable

Waveform at 32Mbps line rate, 1m cable.

Waveform at 32MHz OSC.

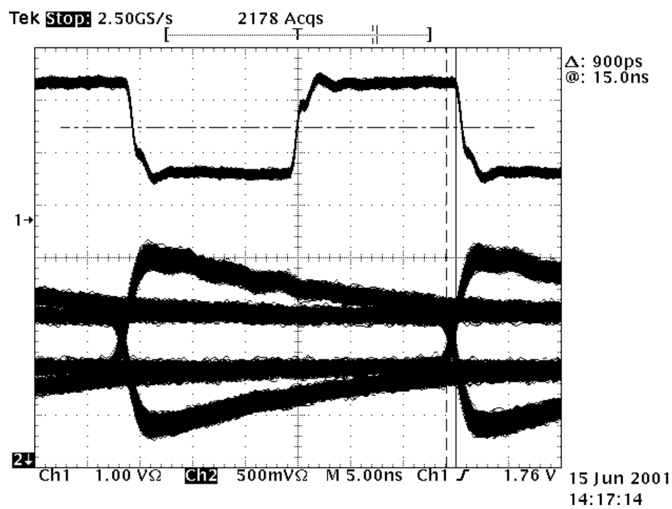
Waveform at RX pin after 1m cable.



Jitter at 32Mbps line rate, 1m cable.

Waveform at 32MHz OSC.

Waveform at RX pin after 1m cable.

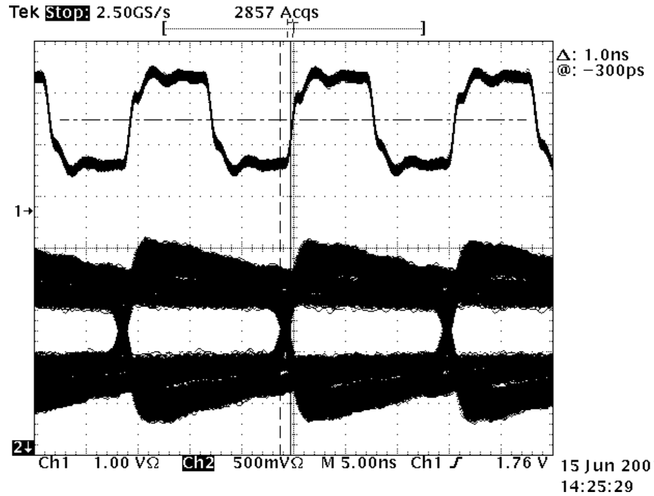


Notes

Waveform at 64Mbps line rate, 1m cable.

Waveform at 64MHz OSC.

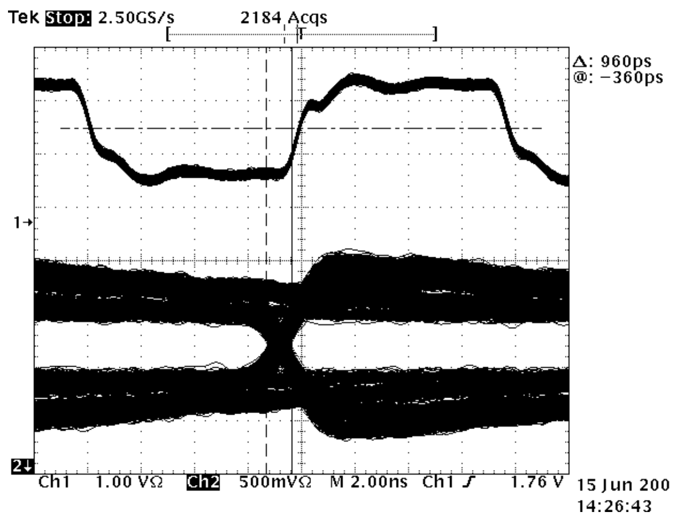
Waveform at RX pin after 1m cable.



Jitter at 64Mbps line rate, 1m cable.

Waveform at 64MHz OSC.

Waveform at RX pin after 1m cable.

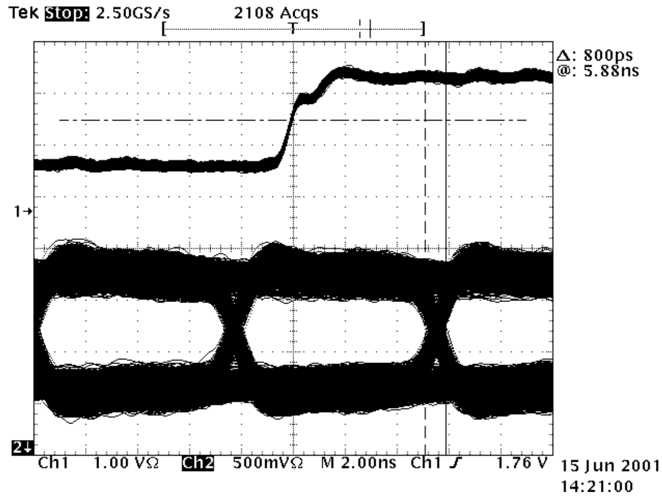


Notes

Waveform at 128Mbps line rate, 1m cable.

Waveform at 64MHz OSC.

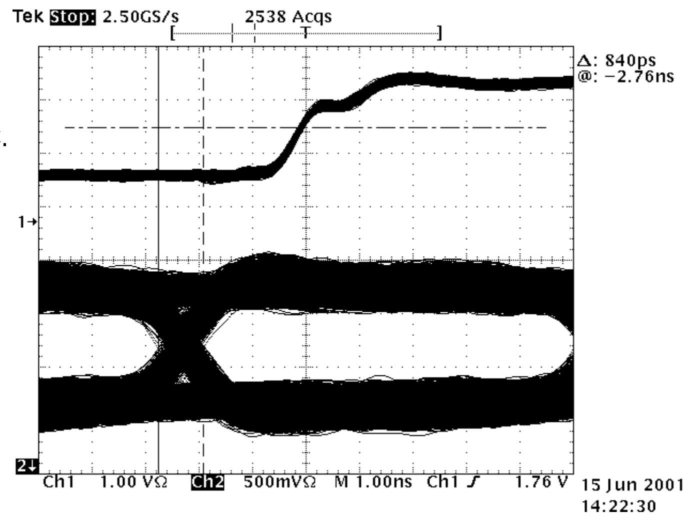
Waveform at RX pin
after 1m cable.



Jitter at 128Mbps line rate, 1m cable.

Waveform at 64MHz OSC.

Waveform at RX pin
after 1m cable.

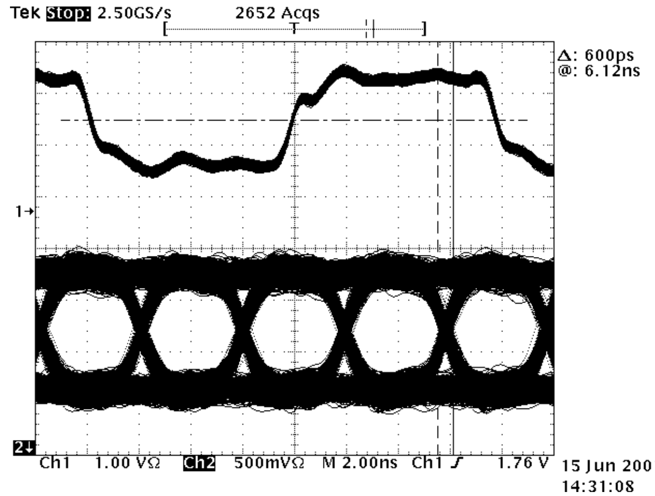


Notes

Waveform at 256Mbps line rate, 1m cable.

Waveform at 64MHz OSC.

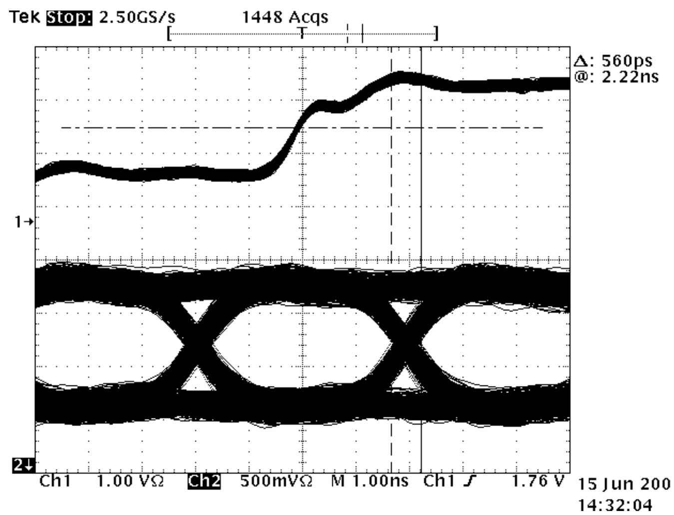
Waveform at RX pin after 1m cable.



Jitter at 256Mbps line rate, 1m cable.

Waveform at 64MHz OSC.

Waveform at RX pin after 1m cable.



Simulation Over 10m of RG174 Cable

In order to give the end user a wider choice of cables and for comparison purposes, simulations were done for a 10m ideal / loss less RG174 coax cable. The model for this cable can be obtained from the cable vendor. A Spice model is included at the end of this document.

Simulation Over 10m RG174 Cable Without Using Magnetics

Initially, the simulations were done without using any magnetics modules to determine signal quality. The modeling for this simulation is shown in Figure 2.

Notes

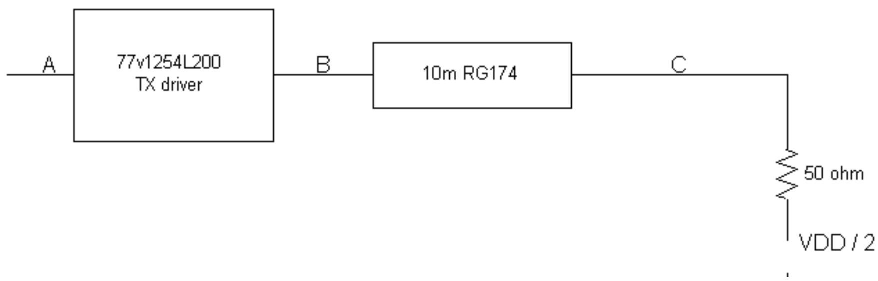


Figure 2 Configuration of Simulation over 10m RG174 Cable

Simulation Results Over 10m RG174 Cable Without Using Magnetics

Using the above configuration, the following results, shown in Figure 3, were seen. Waveforms were captured at points A, B, and C in the above configuration. Point A is the input of the TX driver, Point B is the output at the pad, and Point C is at the end of the 10m cable.

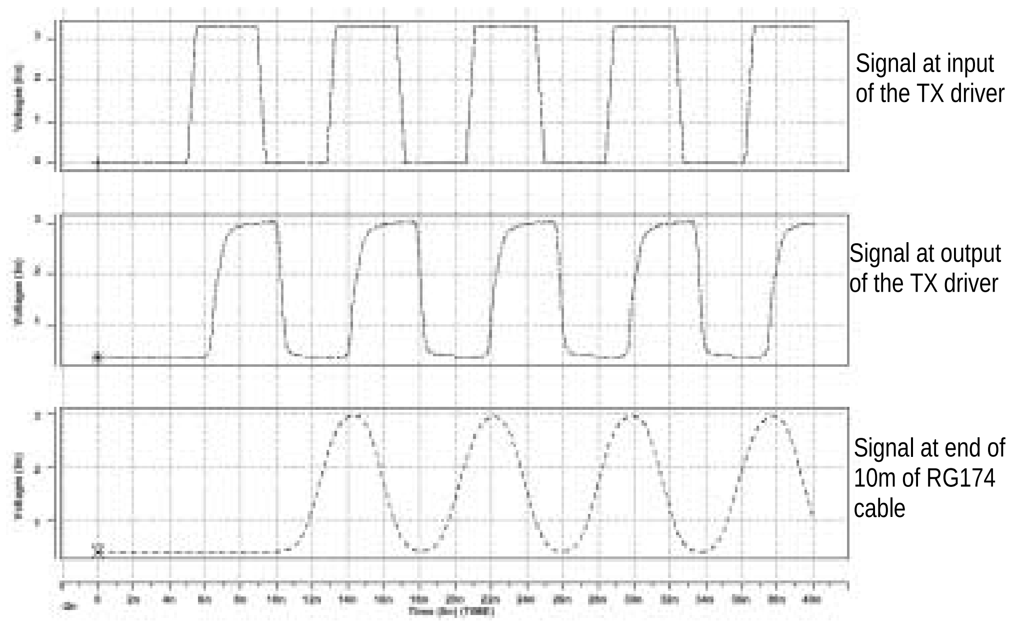


Figure 3 Simulation Results Over 10m RG174 Cable

Simulation Over 10m RG174 Cable Using Magnetics

The above simulation was also performed using the ST6200T magnetics module from Pulse Engineering. The purpose of this simulation was to determine signal quality when ST6200T magnetics is used with the 77v1264L200 to drive 10m of RG174 coax cable.

Termination and configuration used are shown in Figure 4. Note that the system was terminated with a 100ohm resistor to match the cable impedance.

Notes

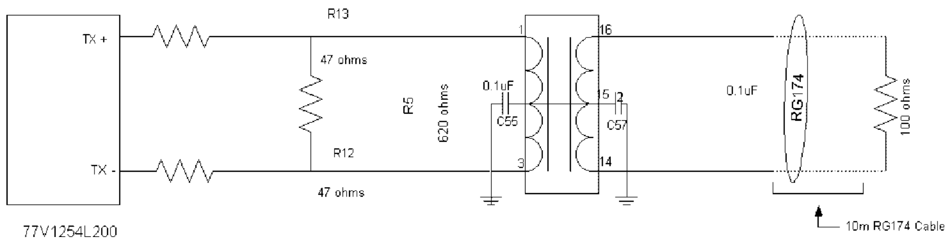


Figure 4 Configuration of Simulation Over 10m RG174 Cable Using ST6200T Magnetics

Simulation Results Over 10m RG174 Cable Using Magnetics

The results from this simulation are shown in Figure 5. These signals show that the 77v1264L200 can drive 10m of RG174 cable when used with the ST6200T magnetics without compromising signal quality.

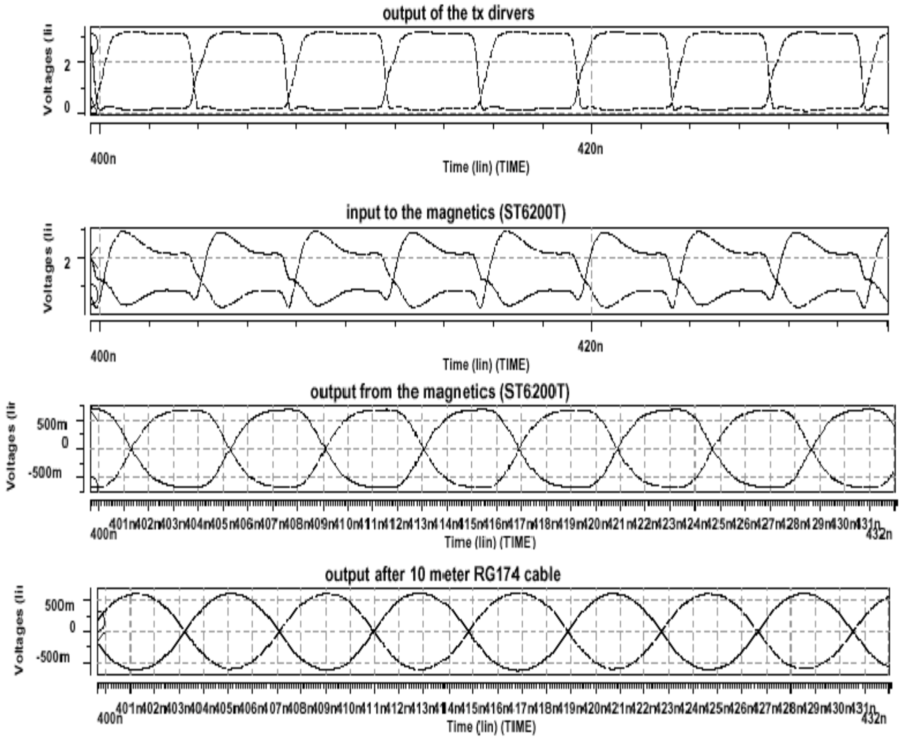


Figure 5 Simulation Results Over 10m RG174 Cable Using ST6200T Magnetics

Simulation Over 1.5m Microstrip Without Connectors

Since backplane is one of the applications that the 77v1264L200 is designed for, simulations were also done to determine signal quality at the TX lines. Typical backplane applications would not include magnetics; therefore, the magnetics module's model was not included in these simulations.

Simulation Over 1.5m Microstrip Without Connectors

It is assumed in this signal that the PCB material used is FR4 and that the signal travels over 50ohm micro-strip lines. Figure 6 shows the signals from the simulation results at 0, 35, 70, and 150 cm from the TX driver.

Notes

Results for Simulation Over 1.5m Microstrip Without Connectors

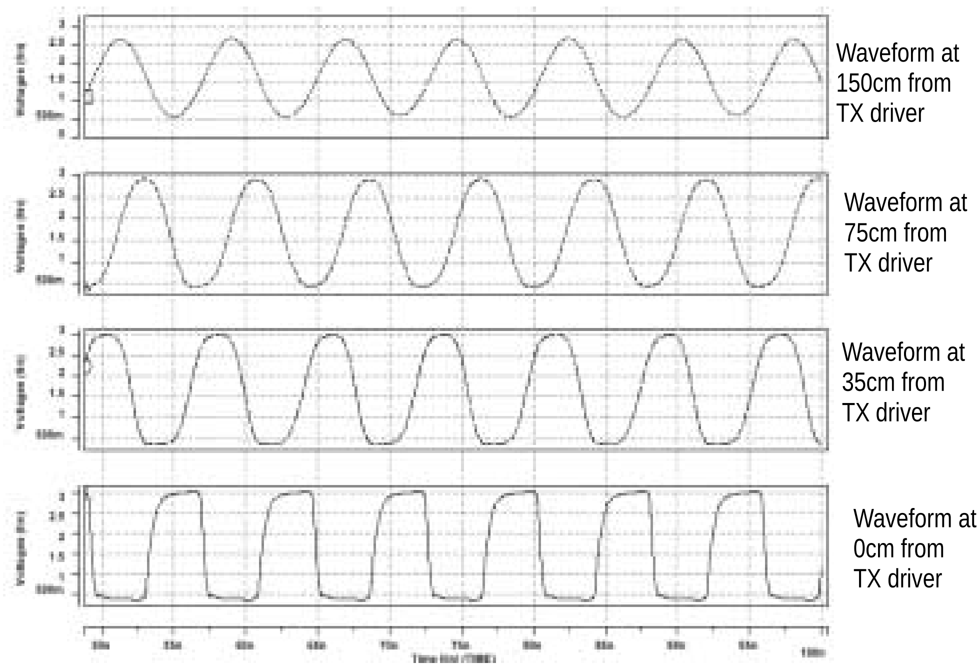


Figure 6 Simulation Results Over 1.5m of 50ohm Microstrip Line

Simulation Over 1.5m Microstrip With Connectors

The above simulation was also done with the assumption that connectors will be used. This was done to make the entire set-up more realistic. Connectors were placed at 0cm, 35cm, 115cm, and 150cm from the TX driver. The model of connectors will vary between different applications. A 3.2nH inductance on 0.5inches of copper trace was used to represent the connector. PCB material was assumed to be FR4 in this case also.

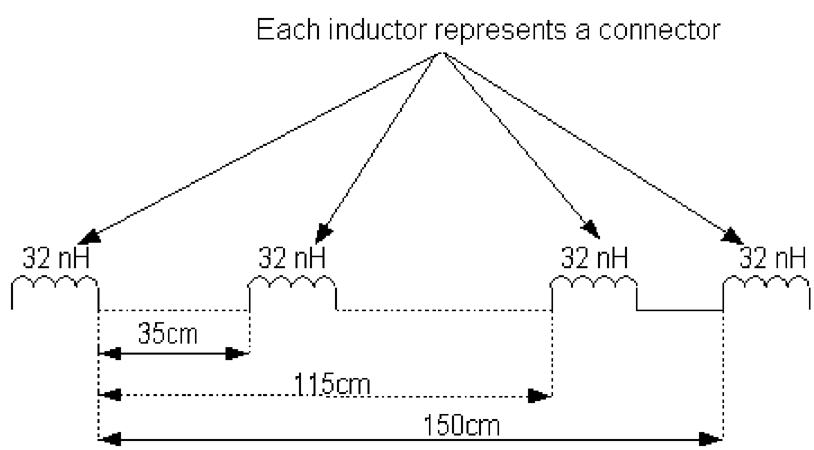


Figure 7 Configuration Used for Simulations with Connectors

Notes

Results for Simulation Over 1.5m Microstrip with Connectors

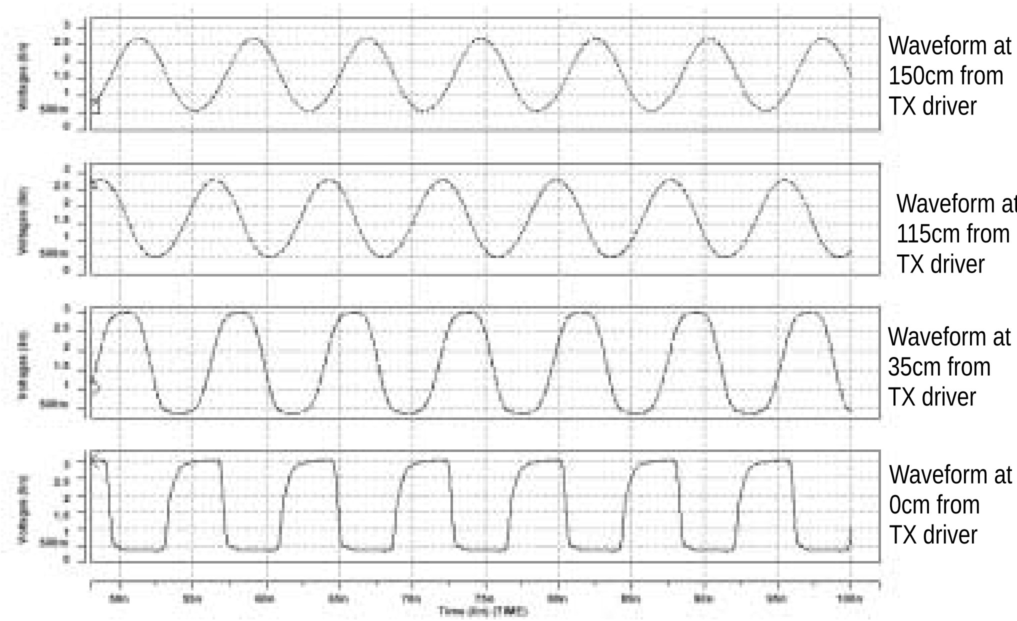


Figure 8 Simulation Results Over 1.5m of 50ohm Microstrip Line Using Connectors

Conclusion

The tests described in this document show that the 77V1264L200XC ATM PHY can transmit and receive data over 10m of UTP5 cable or 1.5m of PCB trace. The PHY has also been tested successfully in different systems and configurations.

Signal quality under both circumstances is acceptable and Jitter measured during lab tests was less than 4ns with no bit errors seen. The simulations and bench tests also show that the Pulse ST6200T magnetics is compatible with IDT77V1264L200 ATM PHYs.

Acknowledgement

The following persons contributed to this document: Fred Nguyen, Al Fang, Zhi Wong, Roland Borges, Rakesh Bhatia, and Phillip Tran.

Matlab Model for RG174 Coaxial Cable

```
%matlab file for transmission lines
%first real data from the manufacturer for 100 meters
figure(1);
clf;
clear
%belden paramaters for attenuation, all in dB in 100 meters
Atten = [1 -0.62;
  10   -10.8;
  50   -19.0
  100  -27.6;
  200  -41.00;
```

Notes

```
   400  -62.4;
   700  -88.50;
   900  -101.6;
   1000 -111.5];

semilogx(Atten(:,1)*1e6, Atten(:,2));
title('data provided by belden for RG-174 cable for 100 meters');
xlabel('frequency in Hz');
ylabel('Attenuation in dB');
grid on;

%approximation for the cable by wave equations
len = 100; %length in meters
for l=1:90
    freq(l) = 10^(l/10);
end

R = 0.3; %resistance per meter
L= 252e-9; %inductance per meter
G = 0; %ignored, very small
C = 100e-12; %per meter
diam = 0.018; %inches

load_resistance = 50; %ohms
voltage_loss = 1-(len*R)/(load_resistance+len*R)
voltage_loss_dB = 20*log10(voltage_loss)
volt_loss_constant = log10(10^-((voltage_loss_dB/len)/20))

for k=1:length(freq)
    gamma(k) = ((R+i*2*pi*freq(k)*L)*(i*2*pi*freq(k)*C))^0.5;
    transfer(k) = exp(-real(gamma(k))*len);
    %attenuation_cons(k) = exp(-R*len/(2*(L/C)^0.5));
    Rac(k) = (((2.16e-7)*freq(k)^0.5)/(pi*diam))/0.0254; % R AC. convert to metric
    R_tot(k) = 2*(Rac(k)^2+R^2)^0.5; %skin effect

        gamma_2(k) = ((R_tot(k)+i*2*pi*freq(k)*L)*(i*2*pi*freq(k)*C*(1-0.002i)))^0.5; %with skin effect
included
    gamma_2(k) = gamma_2(k)+volt_loss_constant; % low freq. deviation
    transfer_2(k) = exp(-real(gamma_2(k))*len);
```

Notes

```
    end

hold on
semilogx(freq, 20*log10(real(transfer_2)), '->');

% now do the same calculation for PCB (circuit board
%first stripline
%values found by Hyperlynx

for l=1:110
    freq(l) = 10^(l/10);
end
len_PCB = 30; %inches
R_PCB = 0.088; %resistance per inch
L_PCB= 8.8e-9; %inductance per inch
G_PCB = 0; %ignored, very small
C_PCB = 3.5e-12; %per inch
W = 7e-3; %width inches
T = 1.4e-3; %length inches

% calculation of DC loss
load_resistance = 50; %ohms
voltage_loss = 1-(len_PCB*R_PCB)/(load_resistance+len_PCB*R_PCB);
voltage_loss_dB = 20*log10(voltage_loss);
volt_loss_constant = log10(10^-((voltage_loss_dB/len_PCB)/20))

%low freq. impedance can be modeled as a multiplicative factor
for k=1:length(freq)
    Rac_PCB(k) = (((2.16e-7)*freq(k)^0.5)/(2*(W+T))); % R AC.
    R_tot_PCB(k) = 2*(Rac_PCB(k)^2+R_PCB^2)^0.5; %total resistance skin effect included, doubled for consistency
    %ignore dielectric loss under 1Ghz
      gamma_PCB(k) = ((R_tot_PCB(k)+i*2*pi*freq(k)*L_PCB)*(i*2*pi*freq(k)*C_PCB))^0.5; %with skin effect included
    gamma_PCB(k) = gamma_PCB(k)+volt_loss_constant; % low freq. deviation
    transfer_PCB(k) = exp(-real(gamma_PCB(k))*len_PCB);
end

figure(2);
semilogx(freq, 20*log10(real(transfer_PCB)), '-.');
```

Notes

```
title('data provided by IPC for FR4 stripline PCB line for 30 inches');
xlabel('frequency in Hz');
ylabel('Attenuation in dB');
grid on;

% %time domain simulation
% z = 30; %inches, the point of simulation
% freq_simulation = 2e8; %200Mhz
% Rac_sim = (((2.16e-7)*freq_simulation^0.5)/(2*(W+T))); % R AC.
% R_tot_sim = 2*(Rac_sim^2+R_PCB^2)^0.5; %total resistance skin effect included, doubled for consistency
% %ignore dielectric loss under 1Ghz
% gamma_sim = ((R_tot_sim+i*2*pi*freq_simulation*L_PCB)*(i*2*pi*freq_simulation*C_PCB))^0.5; %with skin effect included
% gamma_sim = gamma_sim+0.0026 % low freq. deviation
% transfer_sim = exp(-(gamma_sim)*z)+ exp(gamma_sim*z);
%
% transfer_dist_basic = exp(-(gamma_sim)*(z/10))+ exp(gamma_sim*(z/10));
% transfer_dist = transfer_dist_basic^1;
%
% sim_len =100;
% sim_time_len = 10e-9;
% for count = 1:100
%     time_sim(count) = (sim_time_len/sim_len)*(count-1);
%     %lumped
%     volt_transfer_sim(count) = transfer_sim*exp(i*2*pi*freq_simulation*time_sim(count));
%     volt_observed(count) = real(volt_transfer_sim(count));
%     %distributed
%     volt_transfer_dist(count) = transfer_dist*exp(i*2*pi*freq_simulation*time_sim(count));
%     volt_observed_dist(count) = real(volt_transfer_dist(count));
% end
% figure(3);
% clf;
% plot(time_sim, volt_observed, time_sim, volt_observed_dist);
% title('voltage observed vs. time at 30 inches of FR4');
% xlabel('time');
% ylabel('volt');
% grid on;
```