870 Maude Avenue
Sunnyvale, California 94085
Tel (650) 526-1490
Fax (650) 526-1494
e-mail: sales@netchip.com
Internet: www.plxtech.com/netchip

NET2272 USB 2.0 Interface Controller: DMA Transfer Performance Report

Doc #: 669-0213-0100
Revision: 1.0
Date: June 22, 2004

Purpose

This document outlines and analyzes USB bandwidth measurement tests of the NET2272 with DMA transfer and their results.

Test Setup

USB Device

- NET2272 PCI-RDK
- Generic 80MHz EPLD DMA Controller

The NET2272 PCI-RDK is a PCI based development board for the NET2272. When plugged into a PC, the NET2272 PCI-RDK turns the PC into a USB Device.

For the NET2272 local bus interface, the NET2272 PCI-RDK uses an Altera EPLD part. The EPLD runs at 80 MHz and is programmed to perform DMA transactions as well as I/O transactions. DMA request from the NET2272 can be serviced by a simple DMA state machine in the EPLD, or can be passed to the PCI bus on the NET2272 PCI-RDK board. For this test, the simple DMA state machine is used to service DMA request from the NET2272.

USB Host Machine

- Pentium 4, 2.0 GHz
- 512 MB RAM
- Chipset containing Intel® 82801DB I/O Controller Hub 4 (ICH4)
- Microsoft Windows XP

The ICH4 is the USB host controller in our host PC and is one of the fastest USB 2.0 host controllers currently available.

WinMon, NetChip's USB host debug user application, is used to initiate transfers. The host PC loads NcBulk, NetChip's general purpose USB client driver, when the NET2272 PCI-RDK is plugged into the host controller and enumerates.

Test Measurement

Local Bus

- Agilent 16702B Logic Analysis System
- 3ns sample period

For each DMA mode of the NET2272, DMA transaction timing is measured by the Agilent logic analyzer, with sample period of 3 ns.

USB Bus

- CATC Advisor™ USB 2.0 Bus & Protocol Analyzer

In order to measure the USB transfer rate of the NET2272, the CATC USB analyzer is used. The microframe transfer rate* is calculated by counting the number of

bytes transferred in one USB microframe and divide the number of bytes by the microframe period.

The microframe transfer rate, however, cannot be sustained by the host controller. WinMon can only initiate transfers of a finite size. When one transfer completes, the OS must make a context switch back to WinMon so that another transfer can be re-submitted. This results in approximately a 2 Megabyte/second penalty resulting in a sustained transfer rate**.

Results

Bus Mode	DMA Mode	Sample Period	IN Transfer Rate (MB/sec)	OUT Transfer Rate (MB/sec)
8 Bit	Slow	uFrame*	12.29	12.29
		Sustained**	10.29	10.29
	Fast	uFrame	20.48	20.48
		Sustained	18.48	18.48
	Burst	uFrame	26.62	24.58
		Sustained	24.62	22.58
16 Bit	Slow	uFrame	24.57	24.57
		Sustained	22.57	22.57
	Fast	uFrame	36.86	32.77
		Sustained	34.86	30.77
	Burst	uFrame	40.96	32.77
		Sustained	38.96	30.77

* microframe transfer rate
** sustained microframe transfer rate

Table 0.1 USB transfer rate

1. Slow DMA Mode

As shown in the timing diagrams below (Figure 1.1.1 and Figure 1.1.2), in Slow DMA mode, the NET2272 de-asserts DREQ typically within 45 ns after DACK is asserted. Then it asserts DREQ again typically within 21 ns after the end of the previous transaction. The Table 1.1 summarizes the performance of DMA write and DMA read in Slow Mode.

	DREQ to DACK (ns)	DACK to ~DREQ (ns)	~DREQ to DREQ (ns)	Total (ns)
DMA Write	15 ~ 21	42 ~ 45	18 ~ 21	81
DMA Read	15 ~ 21	42 ~ 45	18 ~ 21	81

Table 1.1 Typical DMA timing for Slow Mode DMA transaction

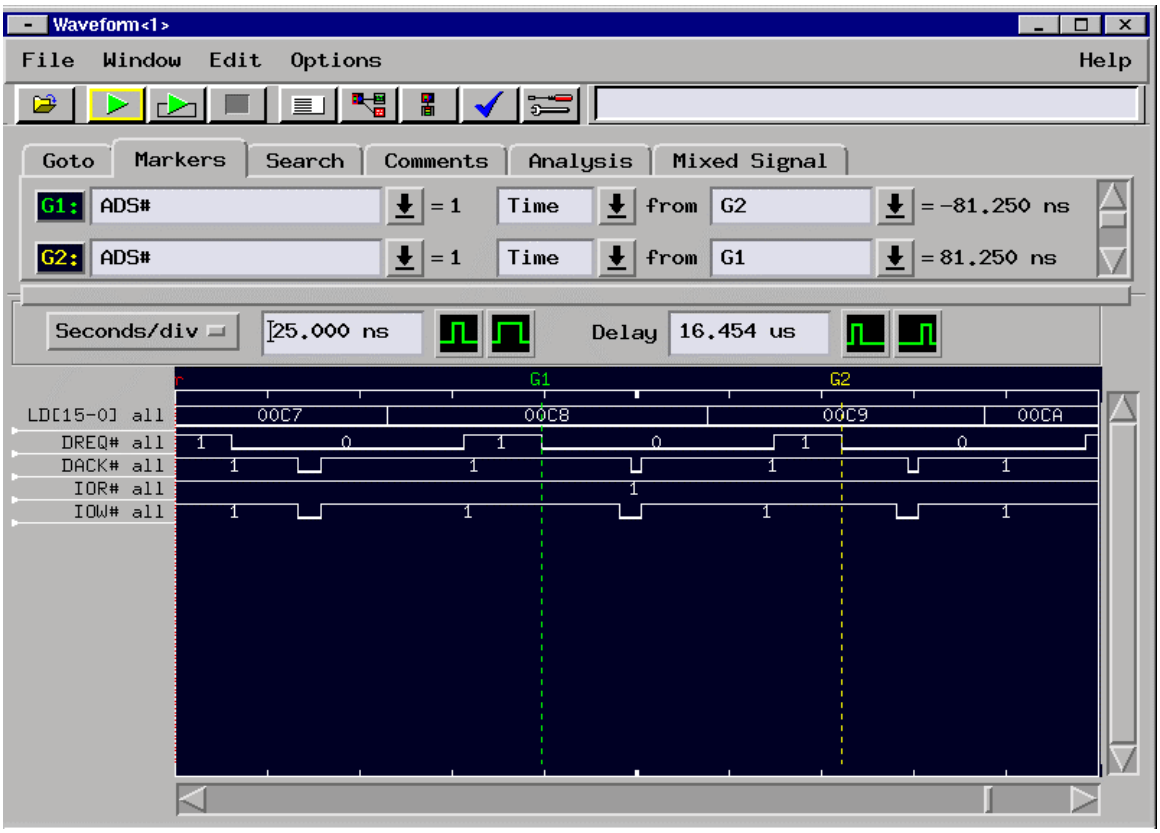

Figure 1.1.1 DMA write (IN transfer) in Slow Mode

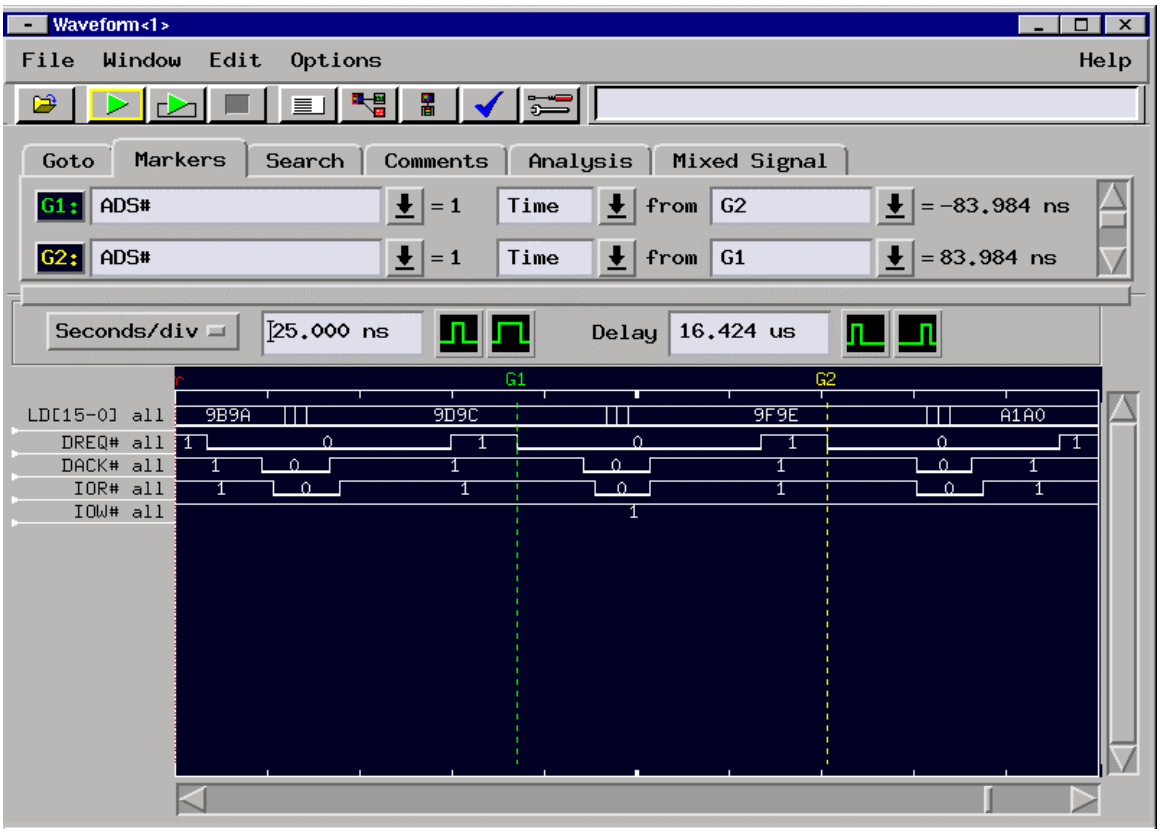

Figure 1.1.2 DMA read (OUT transfer) in Slow Mode

With the cycle period of 81 ns, both DMA write and DMA read transactions in Slow Mode result in 1 byte / 81 ns = 12.3 Mbytes/sec transfer rate in 8 Bit Bus Mode, and 2 bytes / 81 ns = 24.7 Mbytes/sec transfer rate in 16 Bit Bus Mode.

On the USB side, the IN and OUT transfer rates correspond to the DMA write and DMA read transfer rates, respectively. For 8 Bit Bus Mode, the NET2272 can consistently transmit three 512 byte packets in one microframe for IN transfer (Figure 1.2.1) and can consistently receive three 512 byte packets in one microframe for OUT transfer (Figure 1.2.2). Therefore, the microframe transfer rate for both IN and OUT transfers is (3 packets * 512 bytes) / 0.125 us = 12.29 Mbytes/sec, which corresponds to the DMA transfer rate of 12.3 Mbytes/sec.

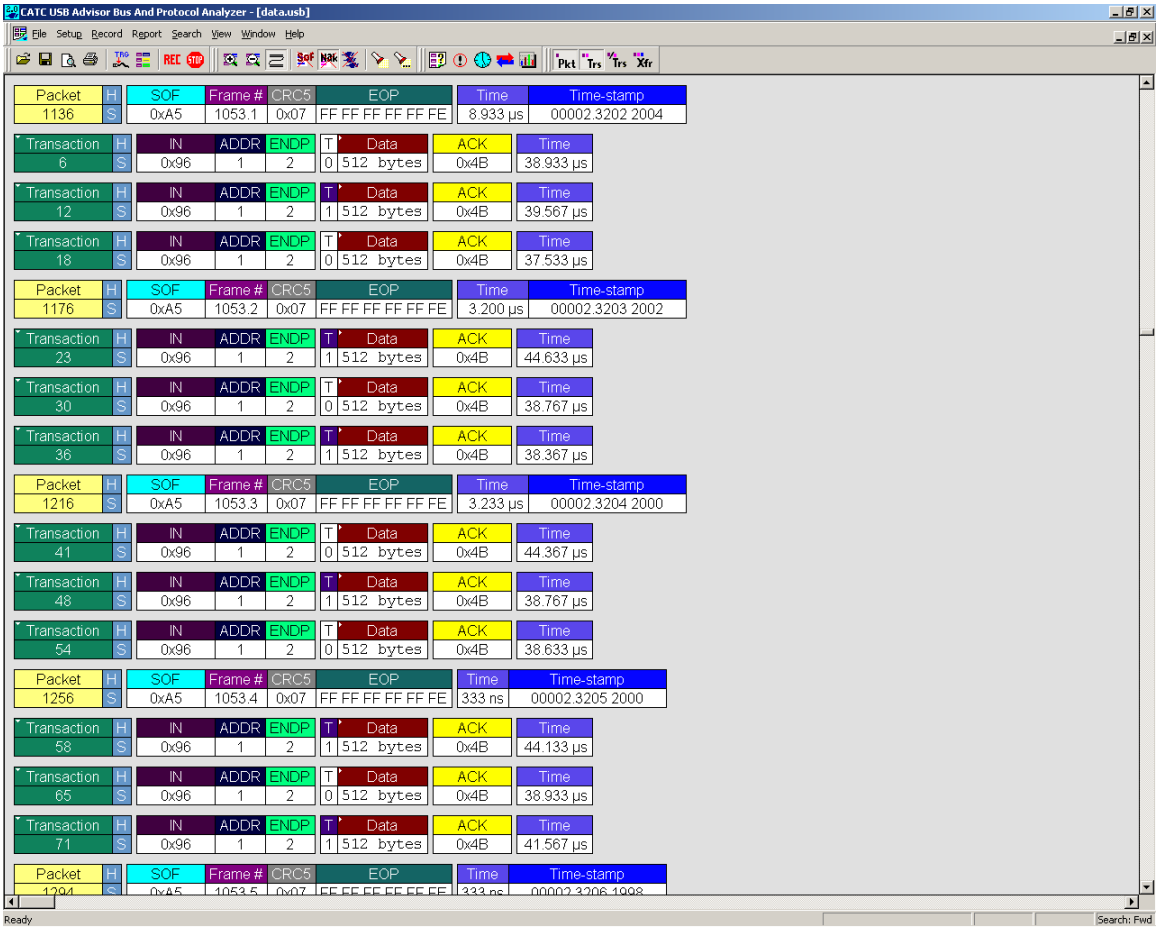

Figure 1.2.1 IN transfer with Slow DMA Mode in 8 Bit Bus Mode

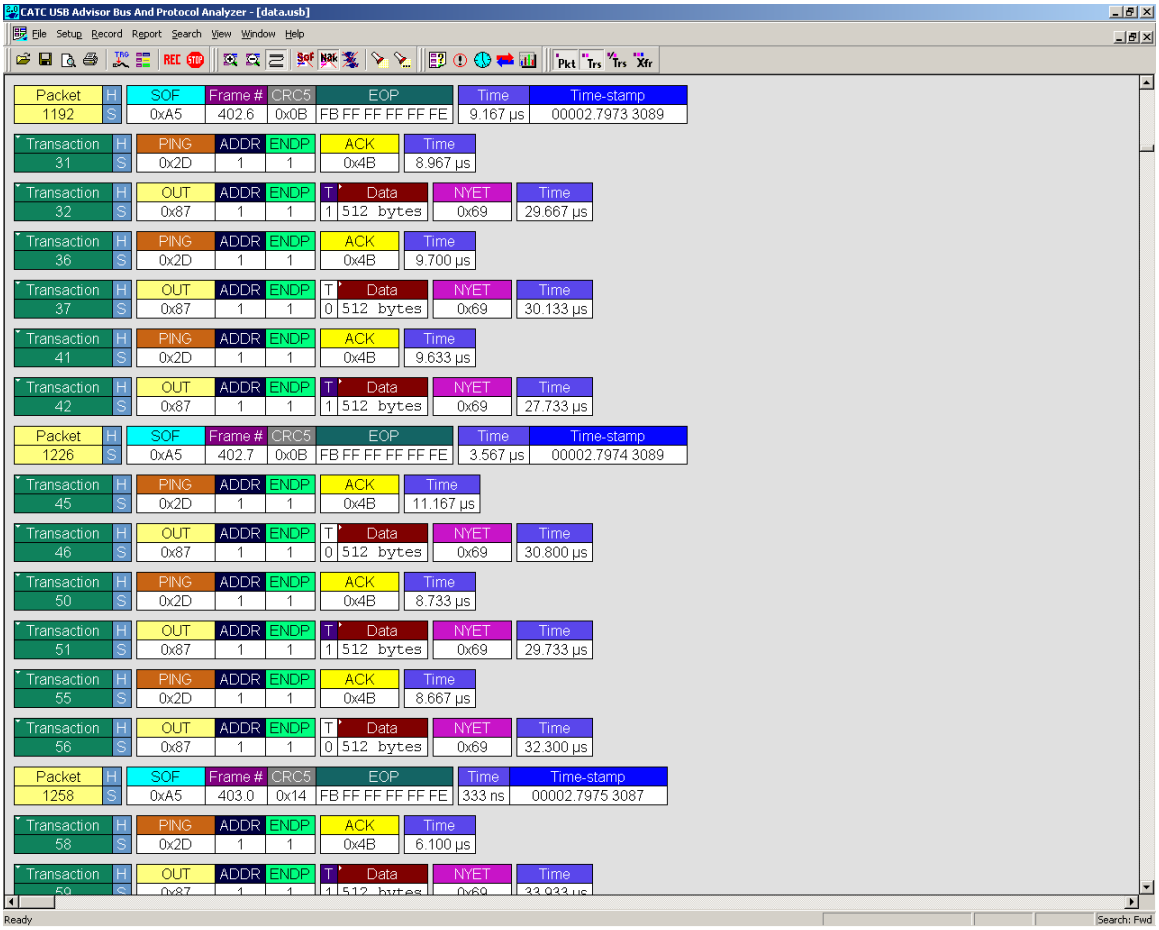

Figure 1.2.2 OUT transfer with Slow DMA Mode in 8 Bit Bus Mode

For 16 Bit Bus Mode, the NET2272 can consistently transmit six 512 byte packets in one microframe for IN transfer (Figure 1.3.1) and can consistently receive six 512 byte packets in one microframe for OUT transfer (Figure 1.3.2). Therefore, the microframe transfer rate for both IN and OUT transfers is (6 packets * 512 bytes) / 0.125 us = 24.57 Mbytes/sec, which corresponds to the DMA transfer rate of 24.7 Mbytes/sec.

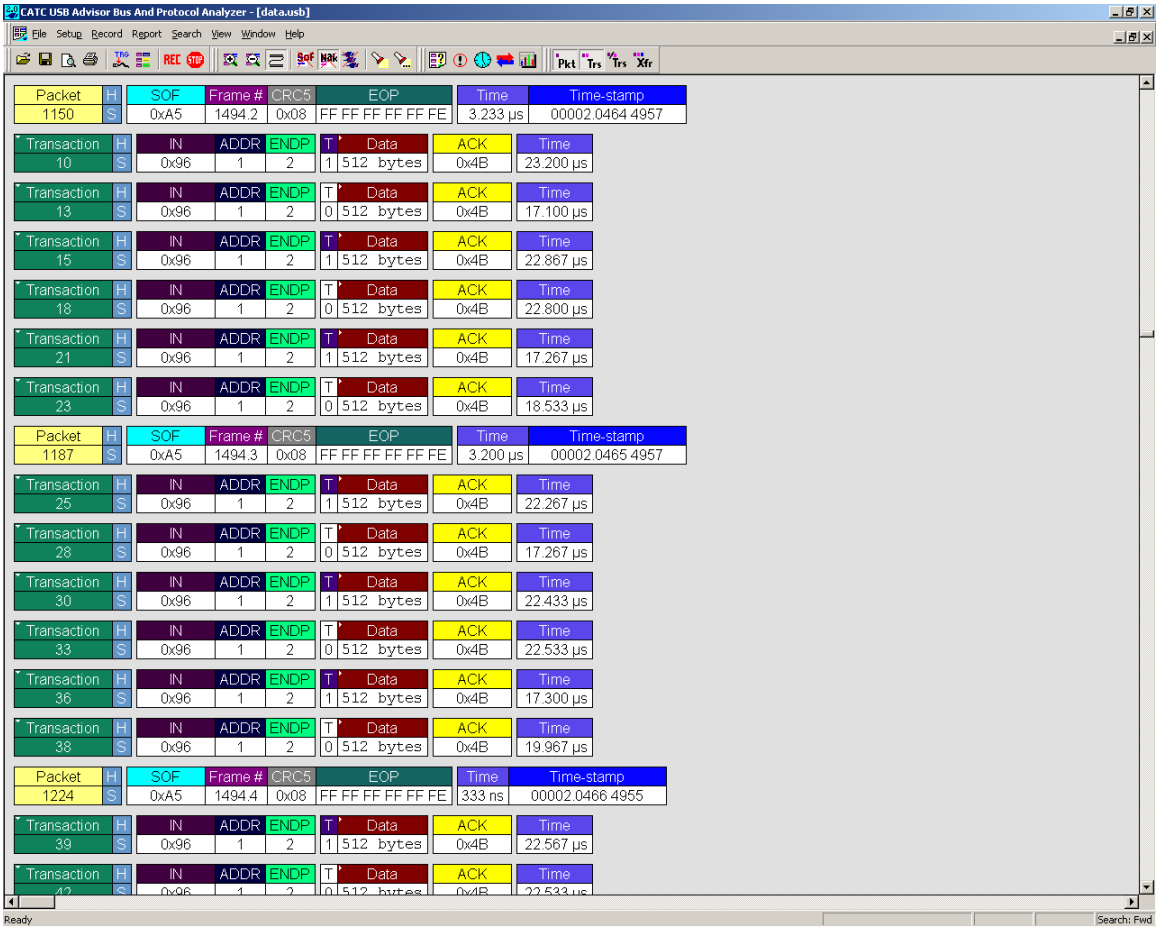

Figure 1.3.1 IN transfer with Slow DMA Mode in 16 Bit Bus Mode

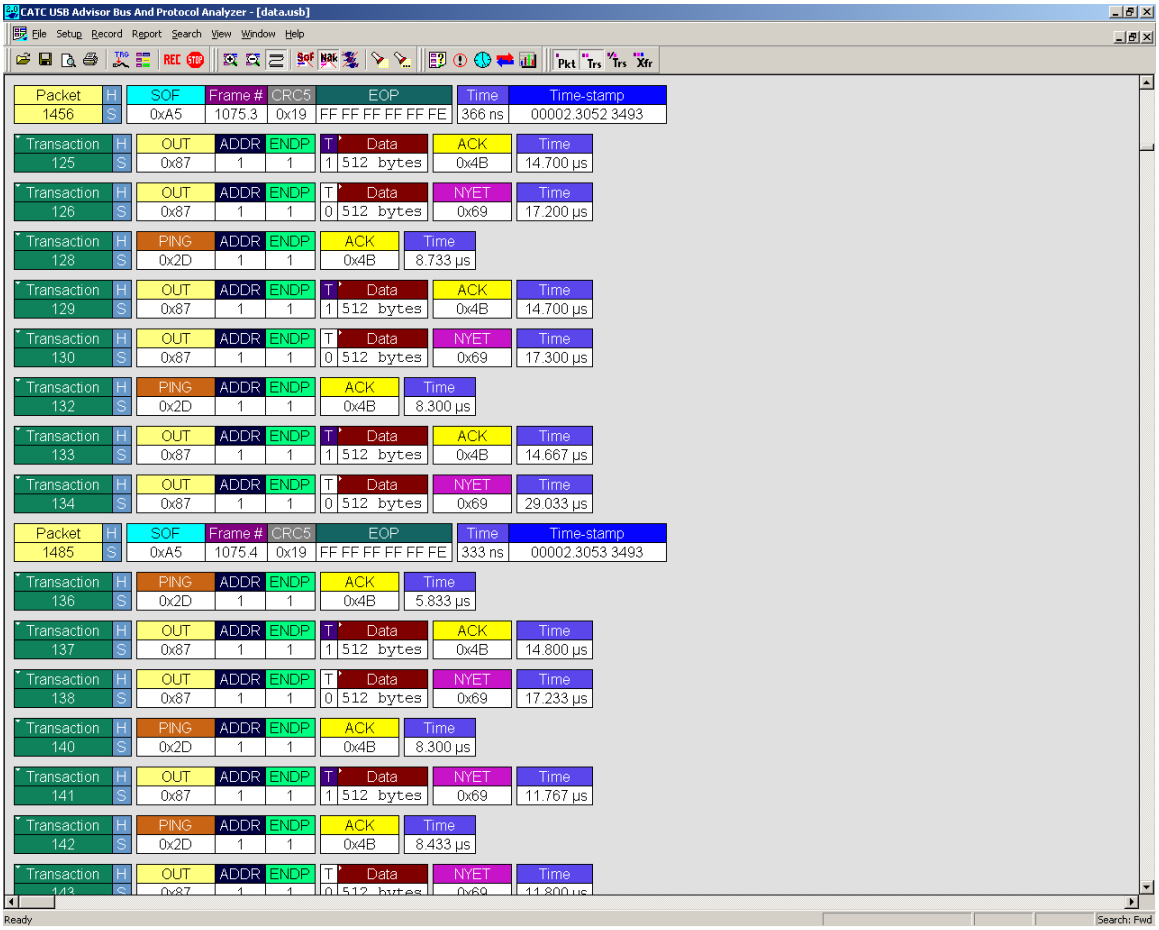

Figure 1.3.2 OUT transfer with Slow DMA Mode in 16 Bit Bus Mode

2. Fast DMA Mode

As shown in the timing diagrams below (Figure 2.1.1 and Figure 2.1.2), in Fast DMA mode, the NET2272 de-asserts DREQ typically within 12 ns after DACK is asserted. Then it asserts DREQ again typically within 18 ns after the end of the previous transaction. Table 2.1 summarizes the performance of DMA write and DMA read in Fast Mode.

	DREQ to DACK (ns)	DACK to ~DREQ (ns)	~DREQ to DREQ (ns)	Total (ns)
DMA Write	15 ~ 21	9 ~ 12	18 ~ 21	48
DMA Read	15 ~ 21	9 ~ 12	18 ~ 21	48

Table 2.1 Typical DMA timing for Fast Mode DMA transaction

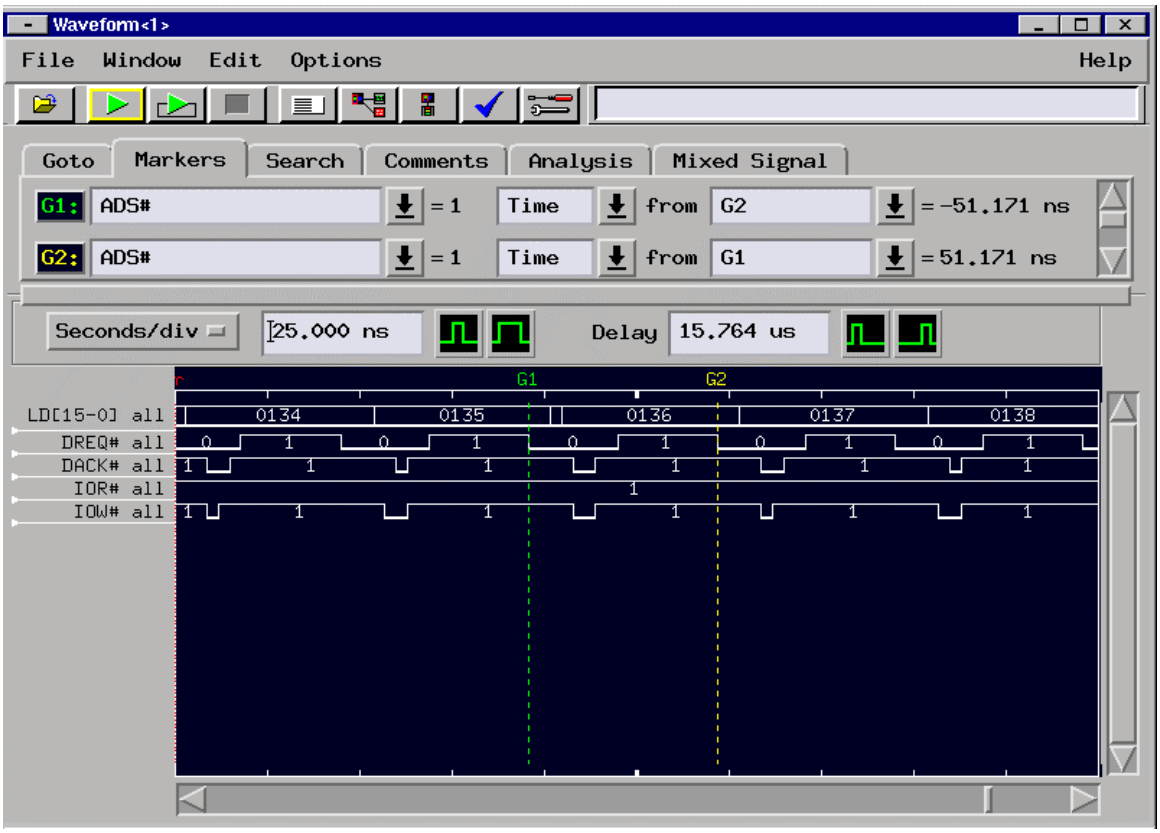

Figure 2.1.1 DMA write (IN transfer) in Fast Mode

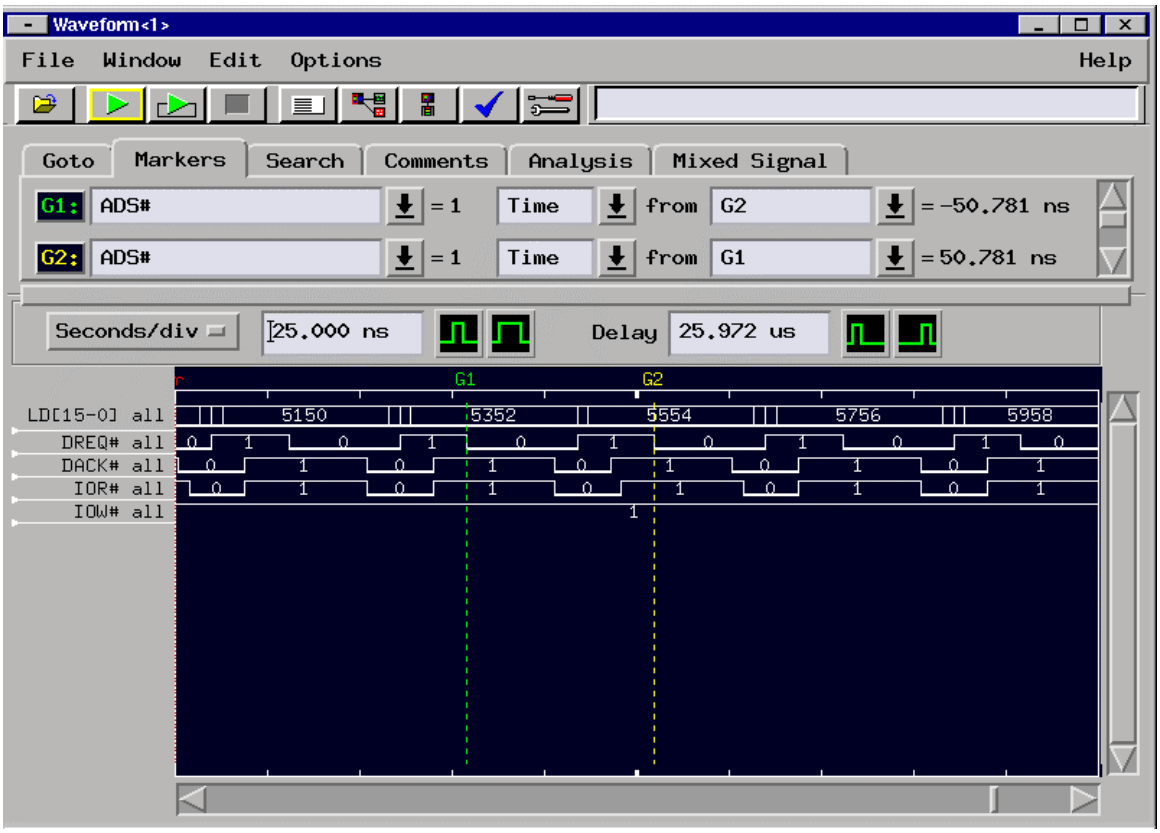

Figure 2.1.2 DMA Read (OUT transfer) in Fast Mode

With the cycle period of 48 ns, both DMA write and DMA read transactions in Fast Mode result in 1 byte / 48 ns = 20.83 Mbytes/sec transfer rate in 8 Bit Bus Mode, and 2 bytes / 48 ns = 41.67 Mbytes/sec transfer rate in 16 Bit Bus Mode.

On the USB side, the IN and OUT transfer rates correspond to the DMA write and DMA read transfer rates, respectively. For 8 Bit Bus Mode, the NET2272 can consistently transmit five 512 byte packets in one microframe for IN transfer (Figure 2.2.1) and can consistently receive five 512 byte packets in one microframe for OUT transfer (Figure 2.2.2). Therefore, the microframe transfer rate for both IN and OUT transfers is (5 packets * 512 bytes) / 0.125 us = 20.48 Mbytes/sec, which corresponds to the DMA transfer rate of 20.83 Mbytes/sec.

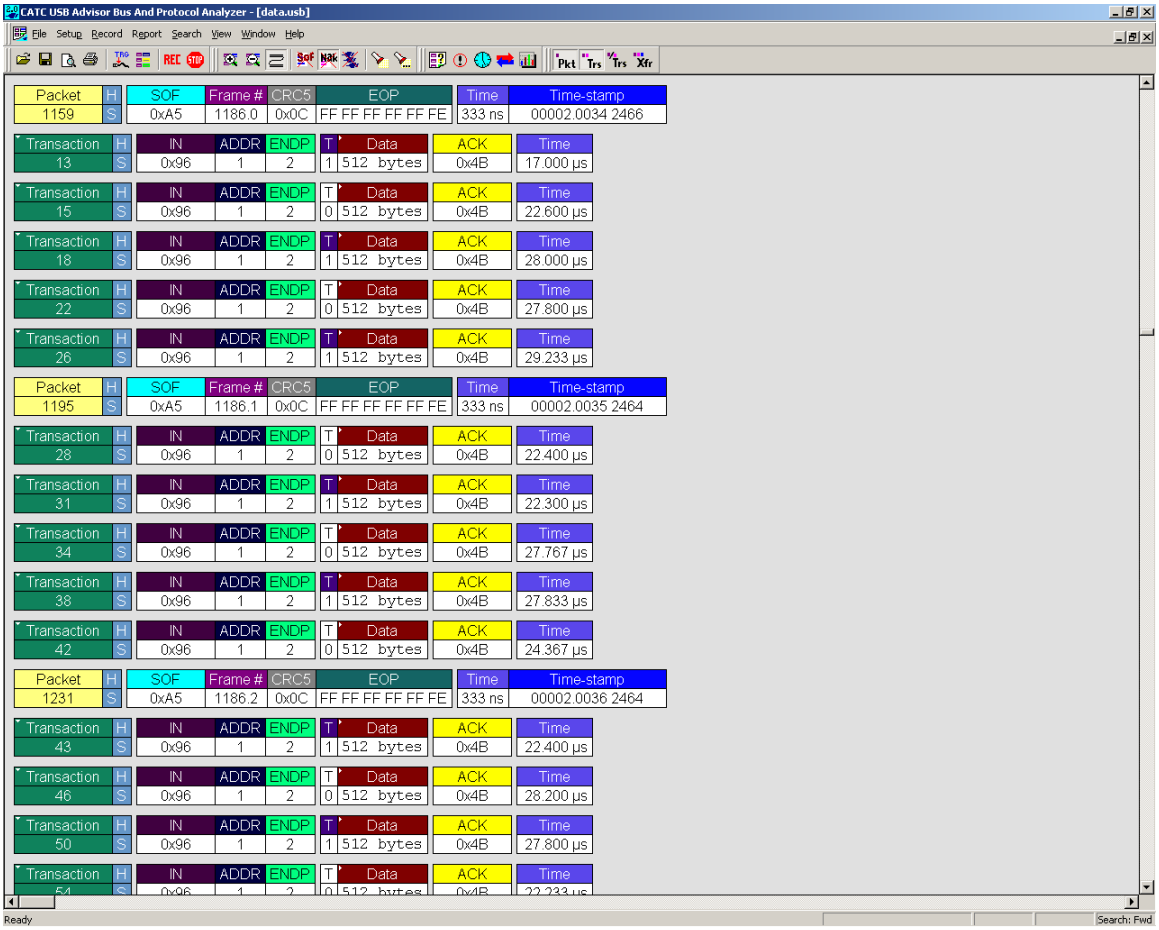

Figure 2.2.1 IN transfer with Fast DMA Mode in 8 Bit Bus Mode

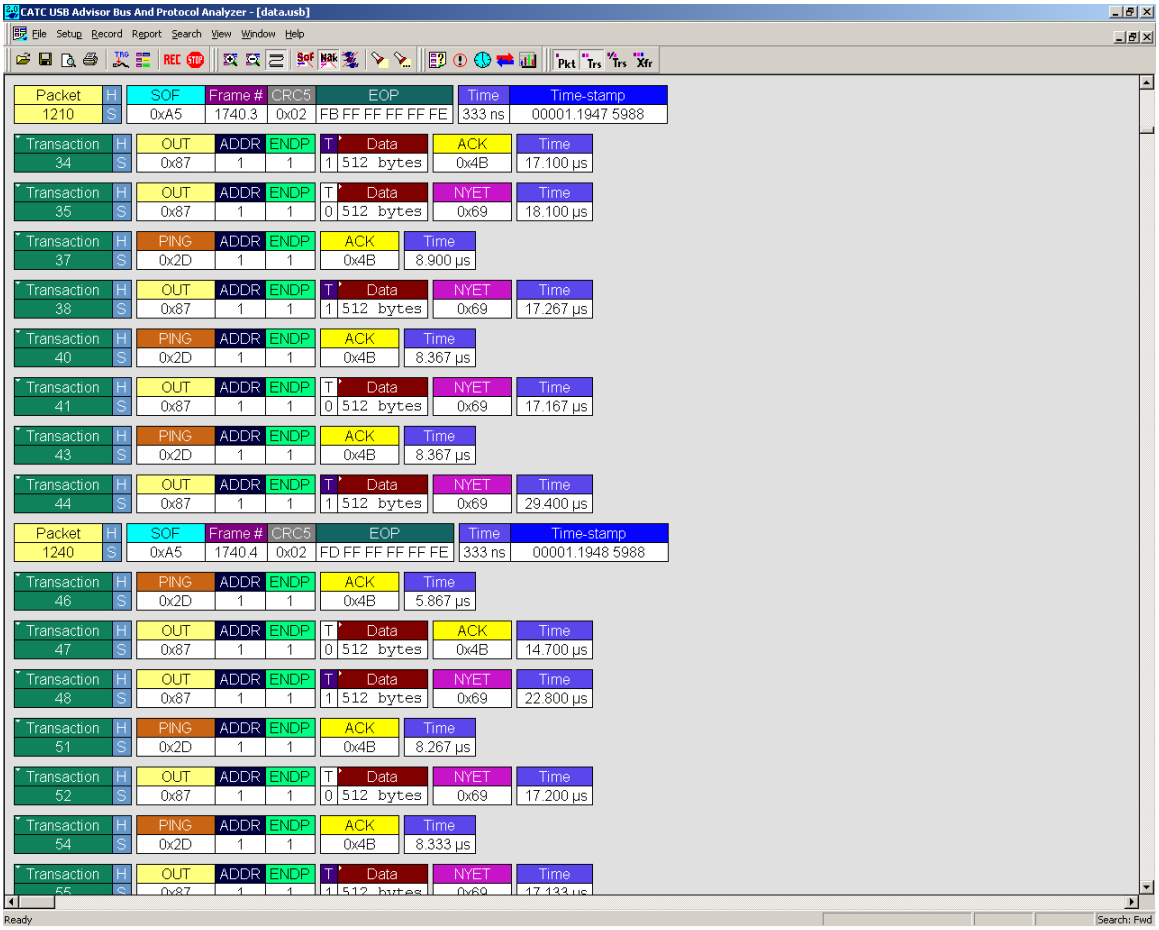

Figure 2.2.2 OUT transfer with Fast DMA Mode in 8 Bit Bus Mode

For 16 Bit Bus Mode, the NET2272 can transmit almost as fast as the maximum bandwidth of the USB host for IN transfer (Figure 2.3.1), and can maximize the bandwidth of the USB host for OUT transfer (Figure 2.3.3). Figure 2.3.2 is the same trace as the IN transfer trace in Figure 2.3.1 but without NAK filter option. As shown in the trace, there are only a couple of NAKs during the IN transfer. The fact that there are only a couple of NAK response indicates that the NET2272 can perform DMA write transactions and transmit the data to the host almost as fast as the USB host can receive. The microframe transfer rate is (9 packets * 512 bytes) / 0.125 us = 36.86 Mbytes/sec. As the OUT transfer trace in Figure 2.3.3 shows, the NET2272 can consistently receive eight 512 byte packets in one microframe without any NYET or NAK. This indicates that the NET2272 maximizes the USB bandwidth that the host can support. The microframe transfer rate is (8 packets * 512 bytes) / 0.125 us = 32.77 Mbytes/sec for OUT transfer, which is less than the DMA read transfer rate of 41.67 Mbytes/sec. Considering that the DMA read transfer rate is faster than the OUT transfer rate, the NET2272 would accept more OUT data without NAK if the host could transmit more OUT data.

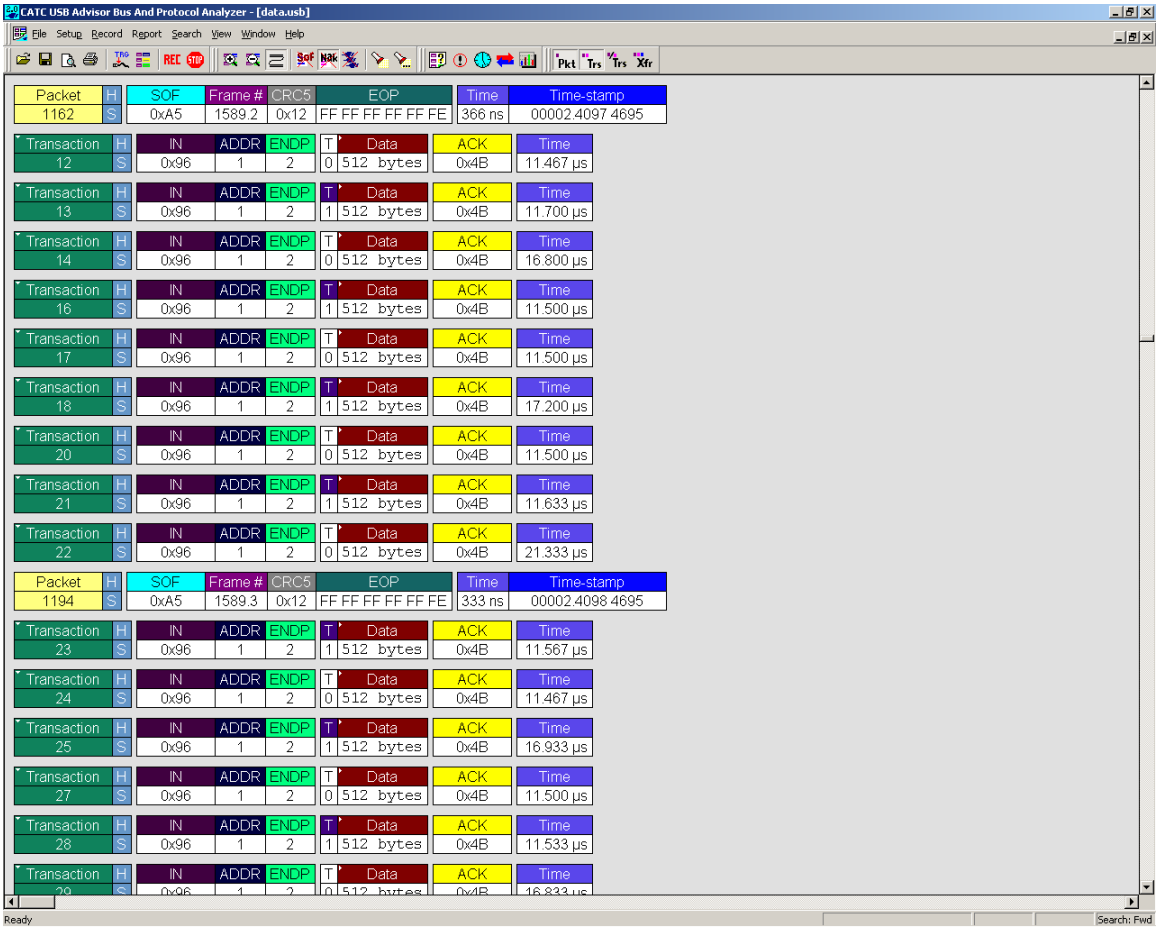

Figure 2.3.1 IN transfer with Fast DMA Mode in 16 Bit Bus Mode

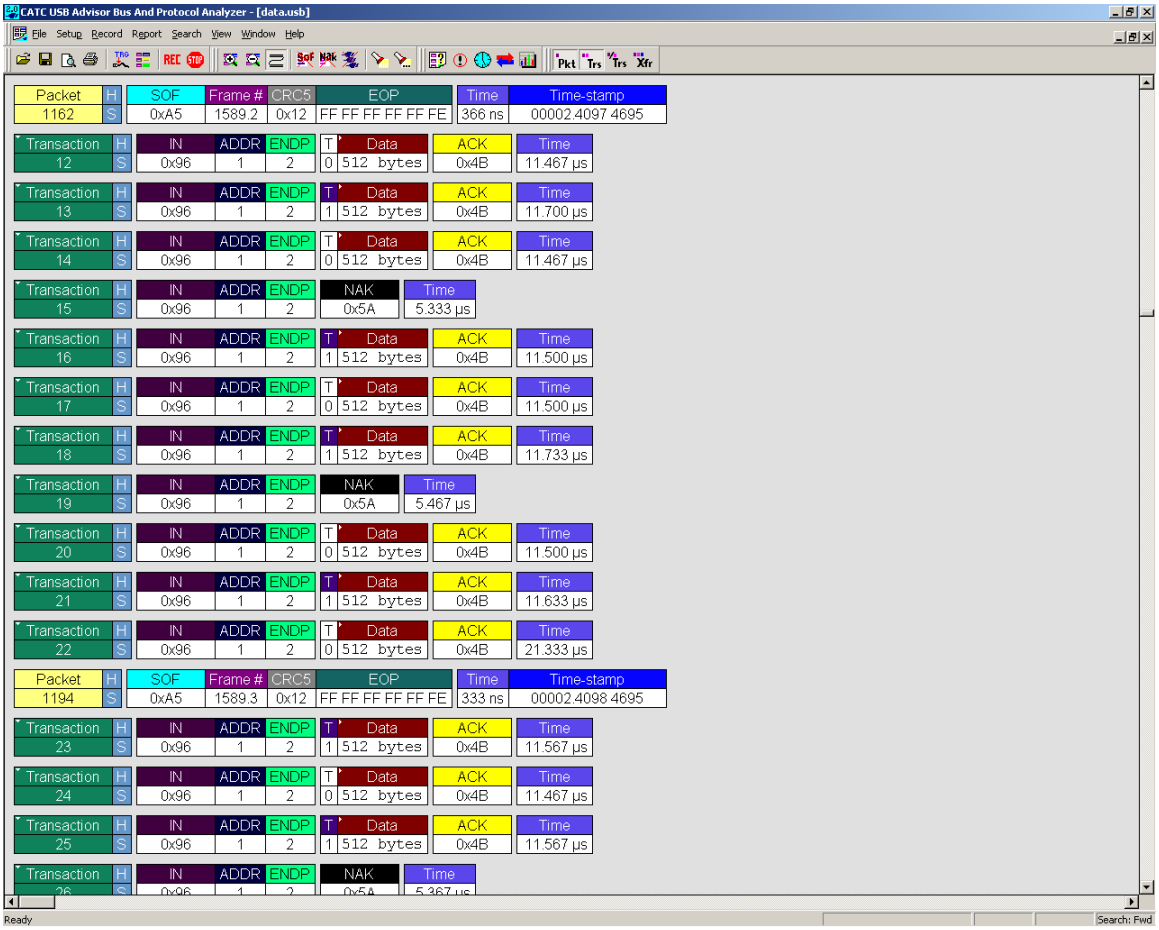

Figure 2.3.2 IN transfer with Fast DMA Mode in 16 Bit Bus Mode (without NAK filter option)

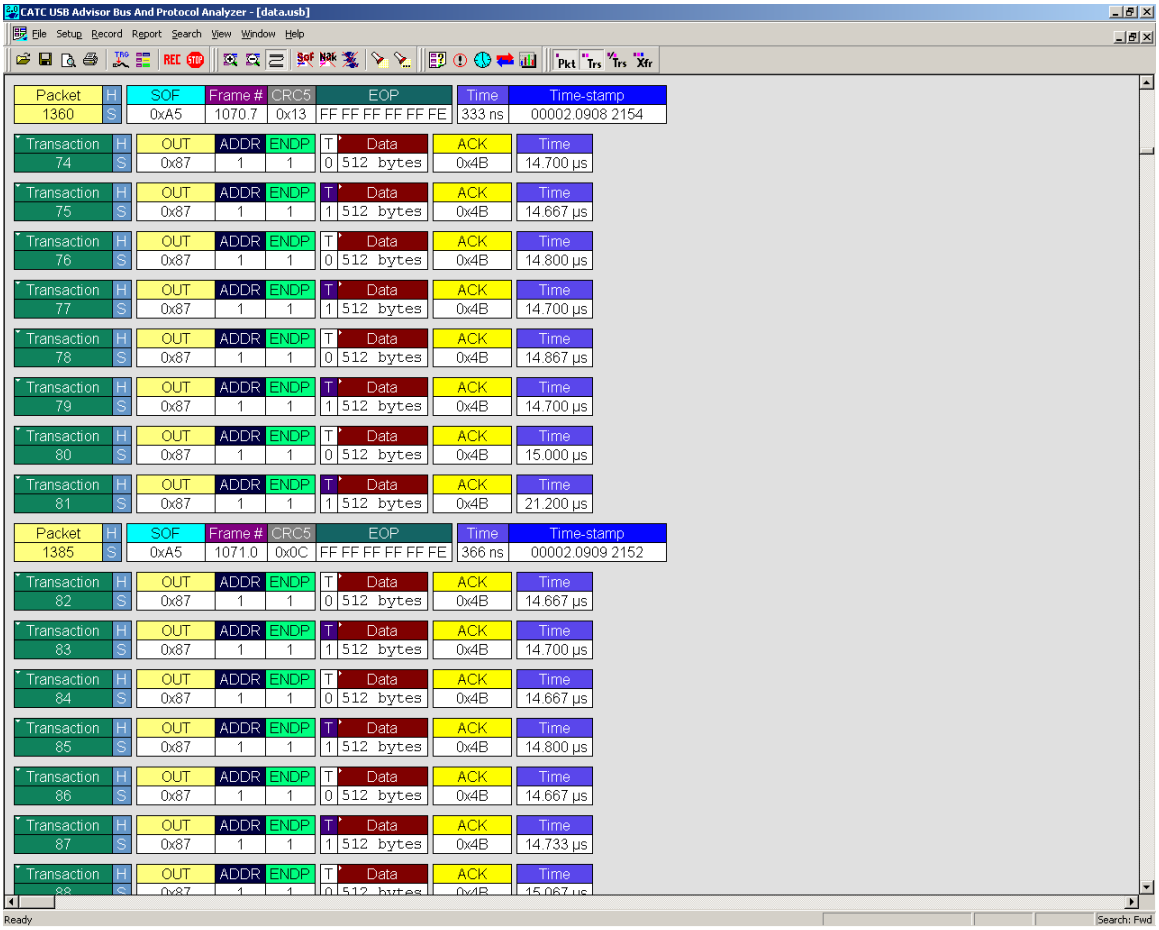

Figure 2.3.3 OUT transfer with Fast DMA Mode in 16 Bit Bus Mode (without NAK filter option)

3. Burst DMA Mode

As shown in the timing diagrams below (Figure 3.1.1 and Figure 3.1.2), in Burst DMA mode, the NET2272 keeps DREQ asserted until the end of the transaction. Table 3.1 summarizes the performance of DMA write and DMA read in Burst Mode.

	DACK width (ns)	~DACK to DACK (ns)	Total (ns)
DMA Write	6.25	30 ~ 33	37
DMA Read	18.25	21 ~ 24	40

Table 3.1 Typical DMA timing for Burst Mode DMA transaction

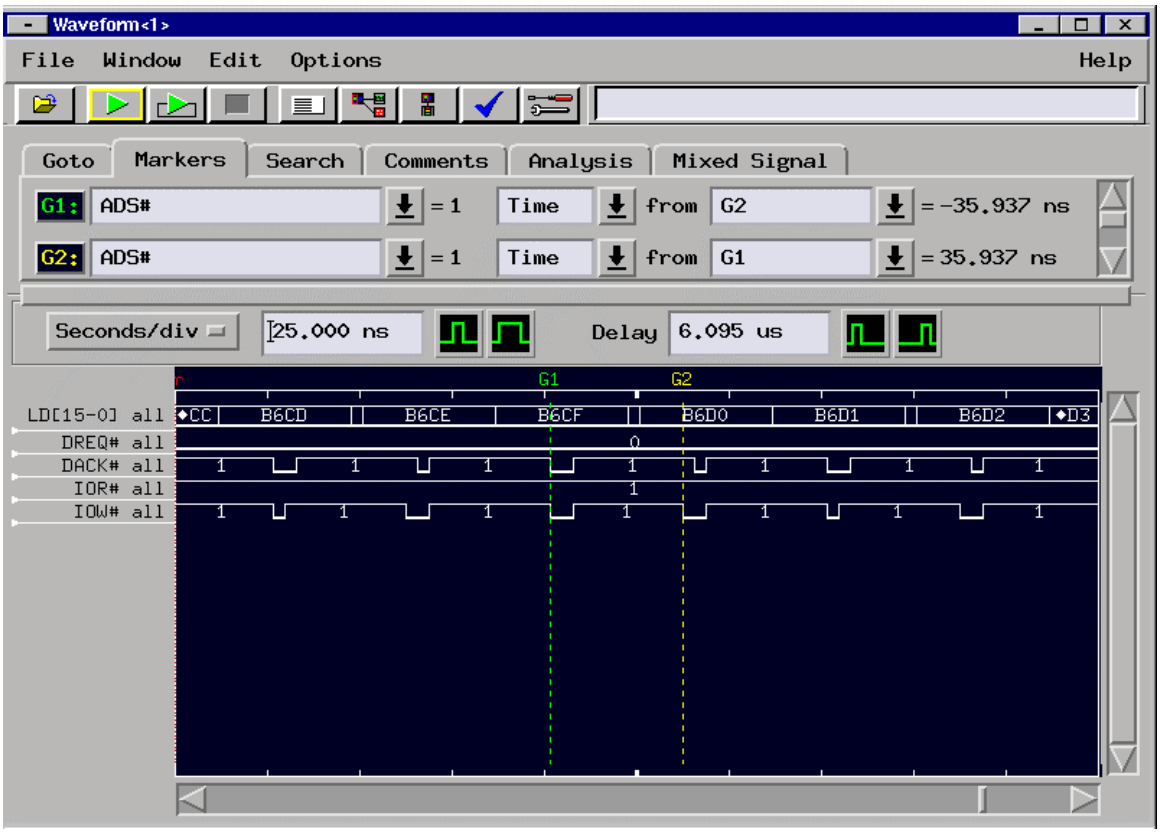

Figure 3.1.1 DMA write (IN transfer) in Burst Mode

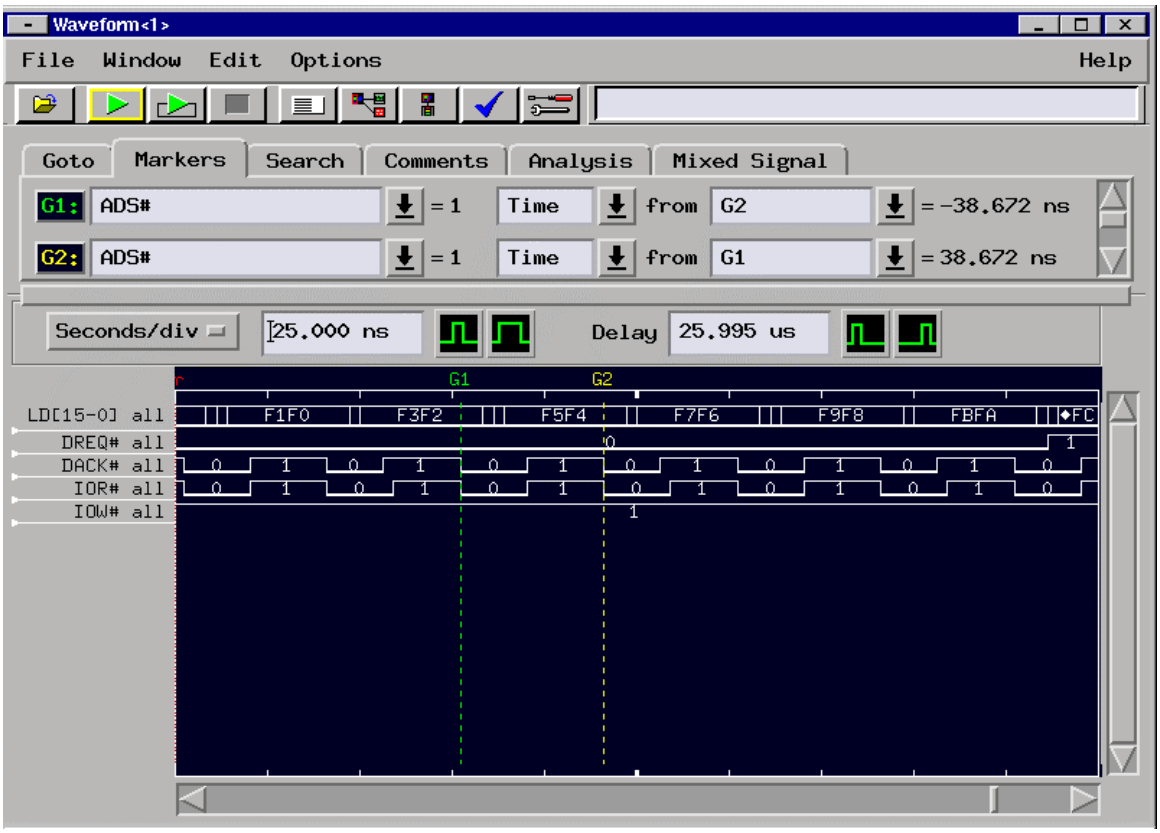

Figure 3.1.2 DMA read (OUT transfer) in Burst Mode

With the cycle period of 37 ns, DMA write transaction in Burst Mode results in 1 byte / 37 ns = 27.03 Mbytes/sec transfer rate in 8 Bit Bus Mode, and 2 bytes / 37 ns = 54.05 Mbytes/sec transfer rate in 16 Bit Bus Mode. For DMA read transaction in Burst Mode, with the cycle period of 40 ns, results in 1 byte / 40 ns = 25.00 Mbytes/sec transfer rate in 8 Bit Bus Mode, and 2 bytes / 40 ns = 50.00 Mbytes/sec transfer rate in 16 Bit Bus Mode.

On the USB side, the IN and OUT transfer rates correspond to the DMA write and DMA read transfer rates, respectively. For 8 Bit Bus Mode, the NET2272 can transmit an average of six and a half 512 byte packets in one microframe for IN transfer (Figure 3.2.1), and can consistently receive six 512 byte packets in one microframe for OUT transfer (Figure 3.2.2). The microframe transfer rate for IN transfer is (6.5 packets * 512 bytes) / 0.125 us = 26.62 Mbytes/sec, which corresponds to the DMA write transfer rate of 27.03 Mbytes/sec. For OUT transfer, the microframe transfer rate is (6 packets * 512 bytes) / 0.125 us = 24.58 Mbytes/sec, which corresponds to the DMA read transfer rate of 25.00 Mbytes/sec.

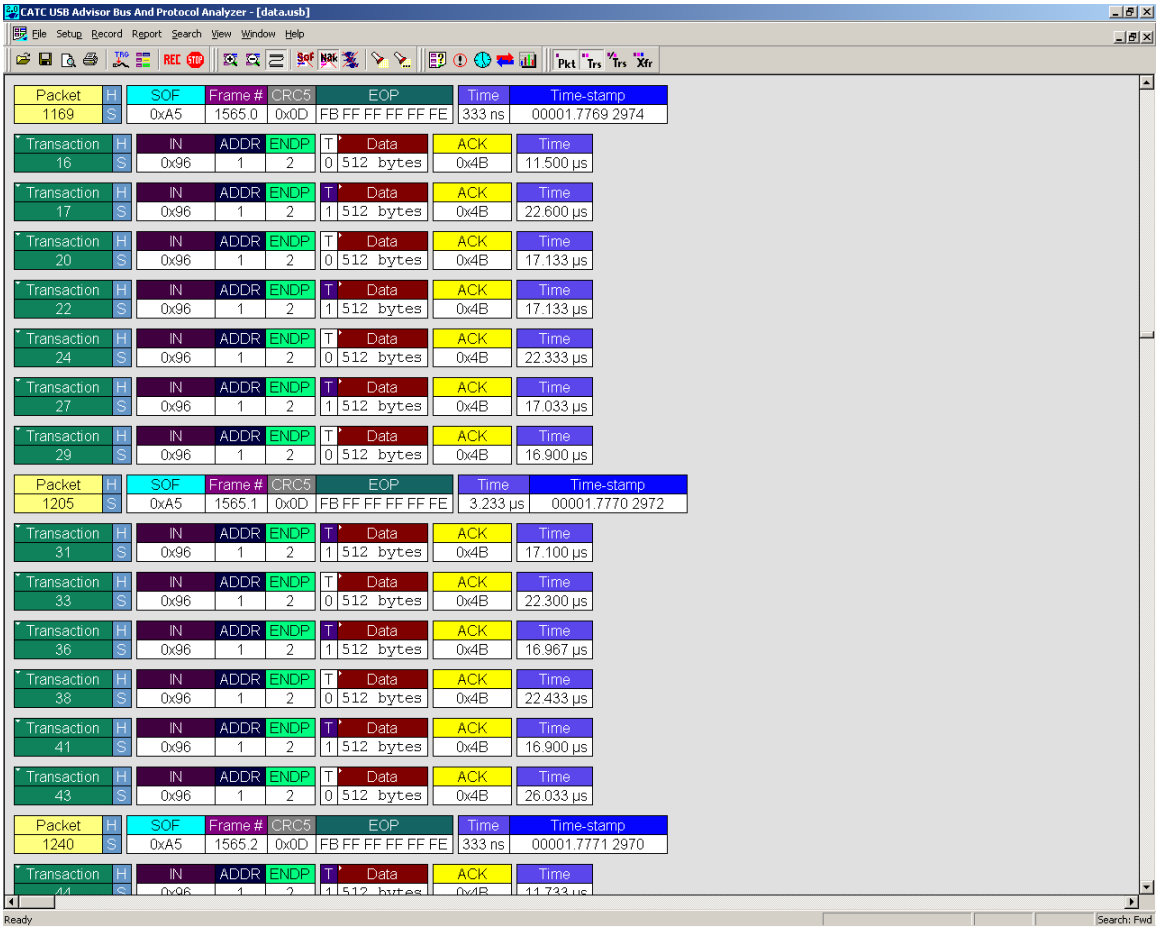

Figure 3.2.1 IN transfer with Burst DMA Mode in 8 Bit Bus Mode

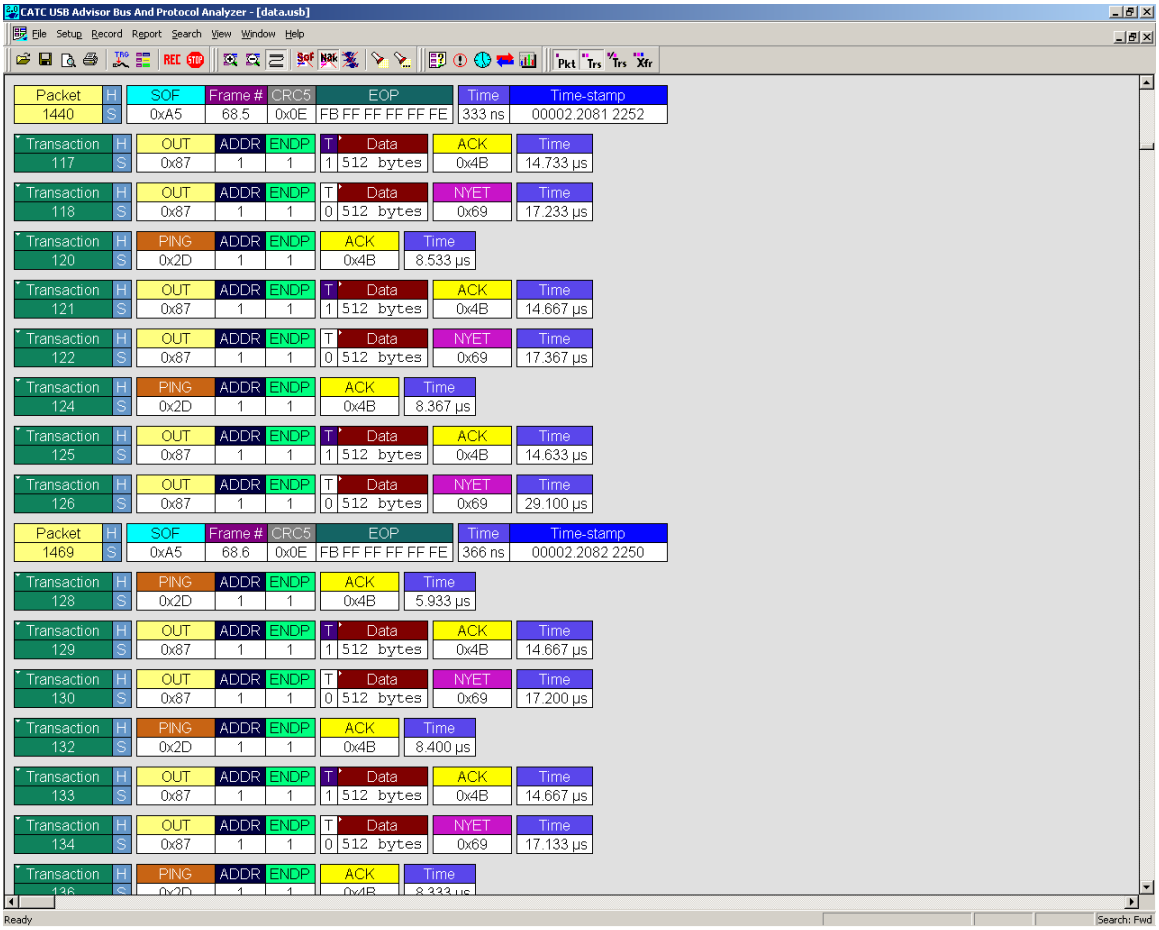

Figure 3.2.2 OUT transfer with Burst DMA Mode in 8 Bit Bus Mode

For 16 Bit Bus Mode, the NET2272 can maximize the USB bandwidth of the host for both IN and OUT transfers; there is no NAK response in both IN and OUT transfers (Figure 3.3.1 IN transfer and Figure 3.3.2 OUT transfer). The NET2272 can consistently transmit ten 512 byte packets in one microframe for IN transfer, which results in the microframe transfer rate of (10 packets * 512 bytes) / 0.125 us = 40.96 Mbytes/sec, and can consistently receive eight 512 byte packets in one microframe for OUT transfer, which results in the microframe transfer rate of (8 packets * 512 bytes) / 0.125 us = 32.77 Mbytes/sec.

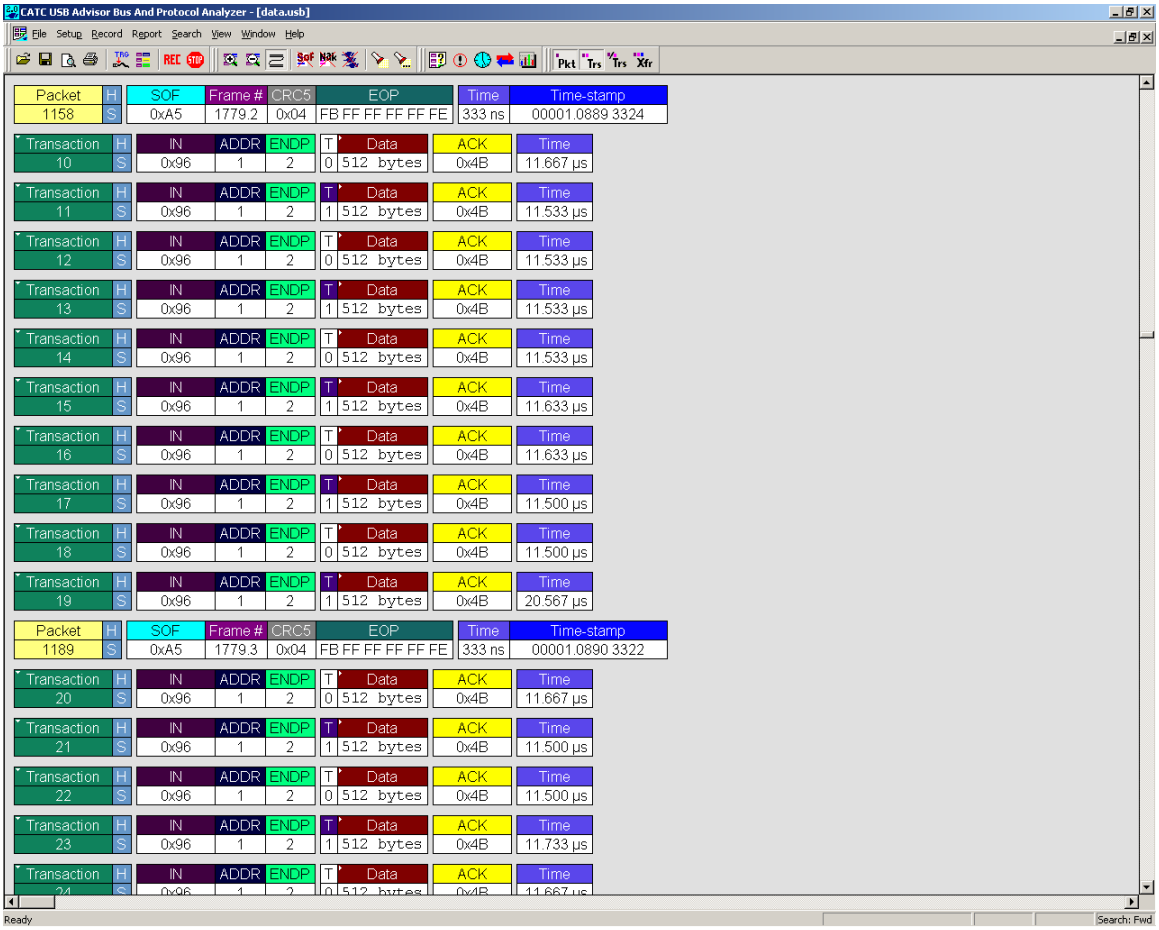

Figure 3.3.1 IN transfer with Burst DMA Mode in 16 Bit Bus Mode (without NAK filter option)

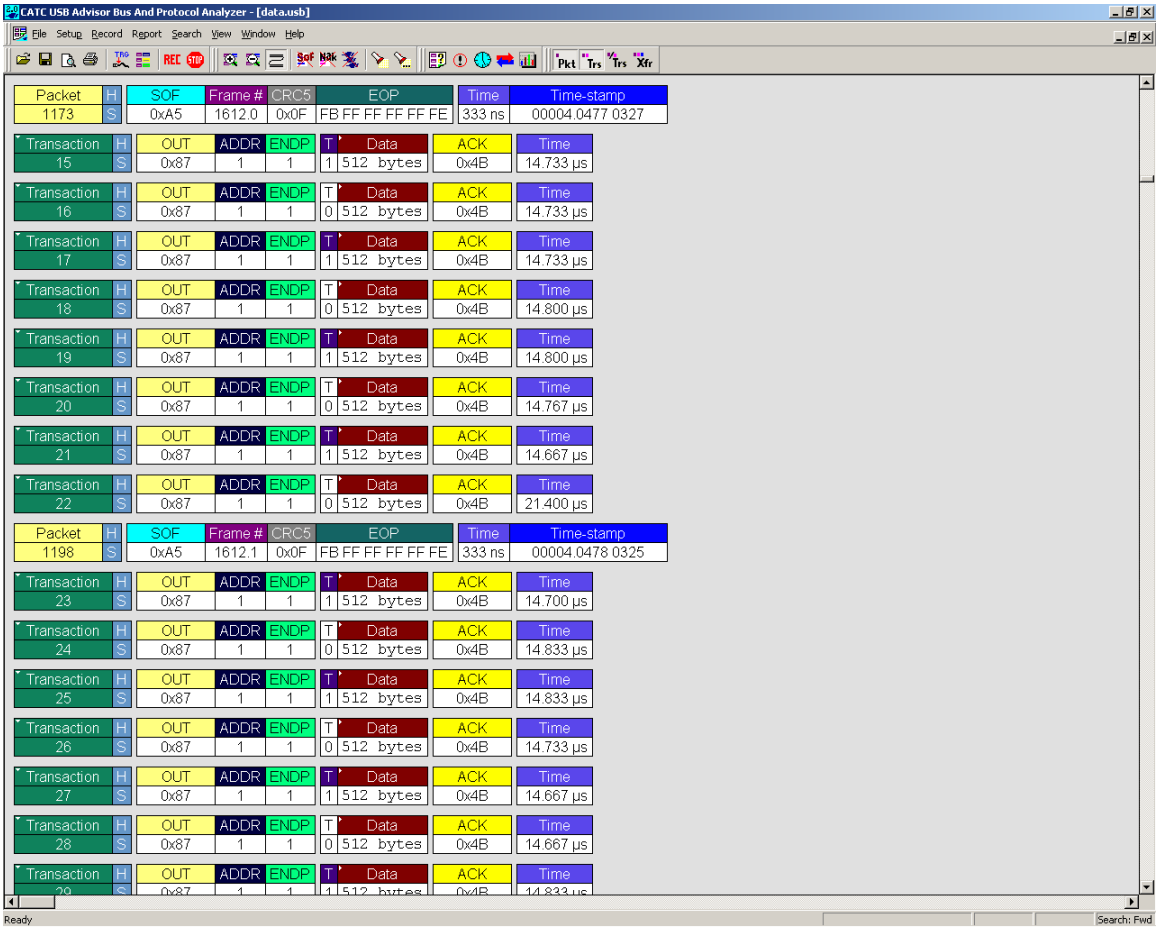

Figure 3.3.2 OUT transfer with Burst DMA Mode in 16 Bit Bus Mode (without NAK filter option)