

### Description

The  $\mu$ PD71051 serial control unit is a CMOS USART designed to provide serial data communications in microcomputer systems. The CPU uses it as a peripheral I/O device and programs it to communicate in synchronous or asynchronous serial data transmission protocols, including IBM bisync.

The USART receives serial data streams and converts them into parallel data characters for the CPU. While receiving serial data, the USART can also accept parallel data from the CPU, convert it to serial, and transmit the data. The USART signals the CPU when it has received or transmitted a character and requires service. The CPU may read complete USART status data at any time.

### Features

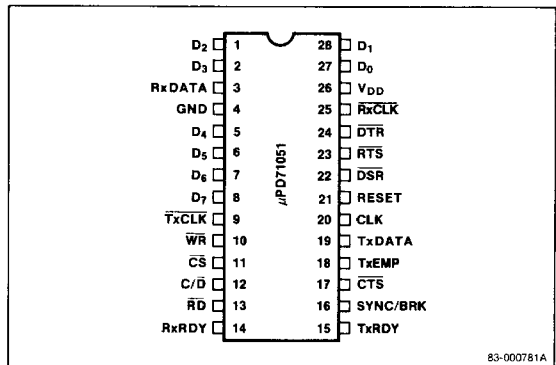
- Synchronous operation
  - One or two SYNC characters
  - Internal/external synchronization
  - Automatic SYNC character insertion
- Asynchronous operation
  - Clock rate: (baud rate) x1, x16, or x64
  - Send stop bits: 1, 1.5, or 2 bits
  - Break transmission
  - Automatic break detection
  - Valid start bit detection
- Baud rate: DC - 240 kbit/s at x1 clock
- Full duplex, double-buffered transmitter/receiver
- Error detection: parity, overrun, and framing
- Five- to eight-bit characters
- Low-power standby mode
- Compatible with standard microcomputers
- Functionally equivalent to (except standby mode) and can replace the  $\mu$ PD8251AF
- CMOS technology
- Single +5 V  $\pm$  10% power supply
- Industrial temperature range -40 to +85 °C
- 28-pin plastic DIP or PLCC or 44-pin plastic QFP
- 8 MHz and 10 MHz

### Ordering Information

Part Number	Clock (MHz)	Package
$\mu$ PD71051C-8	8	28-pin plastic DIP
C-10	10	
GB-8	8	44-pin plastic QFP
GB-10	10	
L-8	8	28-pin PLCC
L-10	10	

### Pin Configurations

#### 28-Pin Plastic DIP



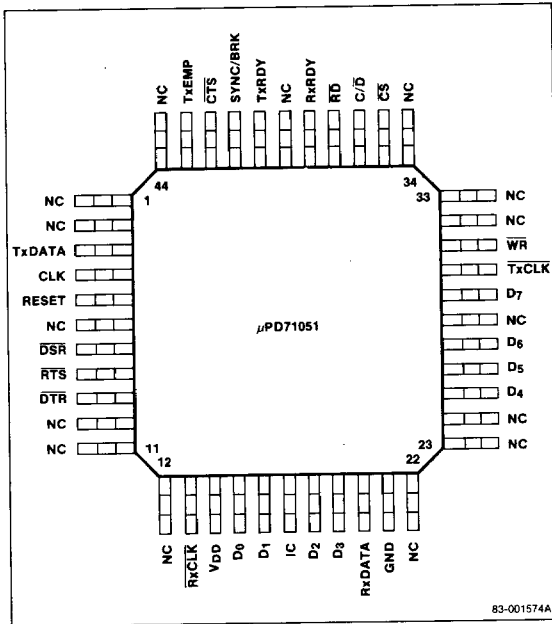
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83-000761A

## μPD71051

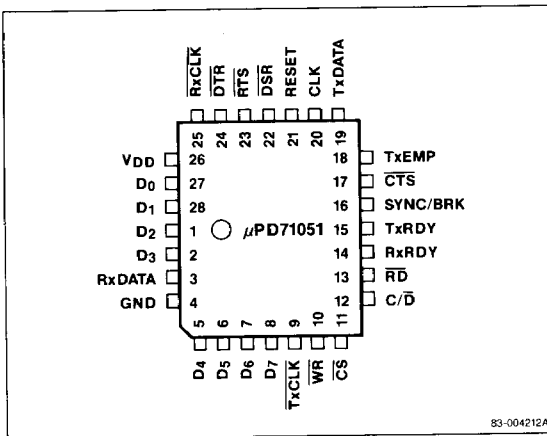
### Pin Configurations (cont)

#### 44-Pin Plastic QFP



83-001574A

#### 28-Pin Plastic Leaded Chip Carrier (PLCC)



83-004212A

### Pin Identification

Symbol	Function
TxDATA	Transmit data output
CLK	Clock input
RESET	Reset input
DSR	Data set ready input
RTS	Request to send output
DTR	Data terminal ready output
RxCLK	Receiver clock input
VDD	+5 V power supply
D7-D0	Data bus
IC	Internally connected (Do not connect any signal to an IC pin)
RxDATA	Receive data input
GND	Ground
TxCLK	Transmitter clock input
WR	Write strobe input
CS	Chip select input
C/D	Control or data input
RD	Read strobe input
RxRDY	Receiver ready output
TxRDY	Transmitter ready output
SYNC/BRK	Synchronization/Break input/output
CTS	Clear to send input
TxEMP	Transmitter empty output
NC	Not connected

### Pin Functions

#### D7-D0 [Data Bus]

D7-D0 are an 8-bit, 3-state, bidirectional data bus. The bus transfers data by connecting to the CPU data bus.

#### RESET [Reset]

A high level to the RESET input resets the μPD71051 and puts it in an idle state. It performs no operations in the idle state. The μPD71051 enters standby mode when this signal falls from a high level to a low level. Standby mode is released when the CPU writes a mode byte to the μPD71051. The reset pulse width must be at least 6 t<sub>CYK</sub> cycles and the clock must be enabled.

## CLK [Clock]

This clock input produces internal timing for the μPD71051. The clock frequency should be at least 30 times the transmitter or receiver clock input frequency ( $\overline{\text{TxCLK}}$ ,  $\overline{\text{RxCLK}}$ ) in sync or async mode with the X1 clock. This assures stable operation. The clock frequency must be more than 4.5 times the  $\overline{\text{TxCLK}}$  or  $\overline{\text{RxCLK}}$  in async mode using x16 or x64 clock mode.

## $\overline{\text{CS}}$ [Chip Select]

The  $\overline{\text{CS}}$  input selects the μPD71051. The μPD71051 is selected by setting  $\overline{\text{CS}} = 0$ . When  $\overline{\text{CS}} = 1$ , the μPD71051 is not selected, the data bus ( $\text{D}_7\text{-D}_0$ ) is in the high impedance state, and the RD and WR signals are ignored.

## $\overline{\text{RD}}$ [Read Strobe]

The  $\overline{\text{RD}}$  input is low when reading data or status information from the μPD71051.

## $\overline{\text{WR}}$ [Write Strobe]

The  $\overline{\text{WR}}$  input is low when writing data or a control byte to the μPD71051.

## $\text{C}/\overline{\text{D}}$ [Control or Data]

The  $\text{C}/\overline{\text{D}}$  input determines the data type when accessing the μPD71051. When  $\text{C}/\overline{\text{D}} = 1$ , the data is a control byte (table 1) or status. When  $\text{C}/\overline{\text{D}} = 0$ , the data is character data. This pin is normally connected to the least significant bit ( $\text{A}_0$ ) of the CPU address bus.

**Table 1. Control Signals and Operations**

$\overline{\text{CS}}$	$\overline{\text{RD}}$	$\overline{\text{WR}}$	$\text{C}/\overline{\text{D}}$	μPD71051	CPU Operation
0	0	1	0	Receive data buffer ↓ Data bus	Read receive data
0	0	1	1	Status register ↓ Data bus	Read status
0	1	0	0	Data bus ↓ Transmit data buffer	Write transmit data
0	1	0	1	Data bus ↓ Control byte register	Write control byte
0	1	1	x	Data bus High impedance	None
1	x	x	x	Data bus High impedance	None

## $\overline{\text{DSR}}$ [Data Set Ready]

$\overline{\text{DSR}}$  is a general-purpose input pin that can be used for modem control. The status of this pin can be determined by reading bit 7 of the status byte.

## $\overline{\text{DTR}}$ [Data Terminal Ready]

$\overline{\text{DTR}}$  is a general-purpose output pin that can be used for modem control. The state of this pin can be controlled by writing bit 1 of the command byte. If bit 1 = 0, then  $\overline{\text{DTR}} = 1$ . If bit 1 = 1, then  $\overline{\text{DTR}} = 0$ .

## $\overline{\text{RTS}}$ [Request to Send]

$\overline{\text{RTS}}$  is a general-purpose output pin that can be used for modem control. The status of this pin can be controlled by writing bit 5 of the command byte. If bit 5 = 1, then  $\overline{\text{RTS}} = 0$ . If bit 5 = 0, then  $\overline{\text{RTS}} = 1$ .

## $\overline{\text{CTS}}$ [Clear to Send]

The  $\overline{\text{CTS}}$  input controls data transmission. The μPD71051 is able to transmit serial data when  $\overline{\text{CTS}} = 0$  and the command byte sets  $\text{TxEN} = 1$ . If  $\overline{\text{CTS}}$  is set equal to 1 during transmission, the sending operation stops after sending all currently written data and the TxDATA pin goes high.

## TxDATA [Transmit Data]

The μPD71051 sends serial data over the TxDATA output.

## TxRDY [Transmitter Ready]

The TxRDY output tells the CPU that the transmit data buffer in the μPD71051 is empty; that is, that new transmit data can be written. This signal is masked by the TxEN bit of the command byte and by the  $\overline{\text{CTS}}$  input. It can be used as an interrupt signal to request data from the CPU.

The status of TxRDY can be determined by reading bit 0 of the status byte. This allows the μPD71051 to be polled. Note that TxRDY of the status byte is not masked by  $\overline{\text{CTS}}$  or TxEN.

TxRDY is cleared to 0 by the falling edge of  $\overline{\text{WR}}$  when the CPU writes transmit data to the μPD71051. Data in the transmit data buffer that has not been sent is destroyed if transmit data is written while TxRDY = 0.

### TxE<sub>MP</sub> [Transmitter Empty]

The μPD71051 reduces CPU overhead by using a double buffer; the transmit data buffer (second buffer) and the transmit buffer (first buffer) in the transmitter. When the CPU writes transmit data to the transmit data buffer (second buffer), the μPD71051 sends data by transferring the contents of the second buffer to the first buffer, after transmitting the contents of the first buffer.

This empties the second buffer and TxRDY is set to 1. The TxEMP output becomes 1 when the contents of the first buffer are sent and the second buffer is empty. Thus, TxEMP = 1 shows that both buffers are empty. In half-duplex operation, you can determine when to change from sending to receiving by testing TxEMP = 1.

When TxEMP = 1 occurs in async mode, the TxDATA pin goes high. When the CPU writes transmit data, TxEMP is set to 0 and data transmission resumes.

When TxEMP = 1 occurs in sync mode, the μPD71051 loads SYNC characters from the SYNC character register and sends them through the TxDATA pin. TxEMP is set to 0 and resumes sending data after sending (one or two) SYNC characters and the CPU writes new transmit data to the μPD71051.

### T<sub>x</sub>CLK [Transmitter Clock]

The T<sub>x</sub>CLK input is the reference clock input that determines the transmission rate. Data is transmitted at the same rate as T<sub>x</sub>CLK in sync mode. In async mode, set T<sub>x</sub>CLK to 1, 16, or 64 times the transmission rate. Serial data from TxDATA is sent at the falling edge of T<sub>x</sub>CLK.

For example, a rate of 19200 baud in sync mode means that T<sub>x</sub>CLK is 19.2 kHz. A rate of 2400 baud in async mode can represent a T<sub>x</sub>CLK of:

- x1 clock = 2.4 kHz
- x16 clock = 38.4 kHz
- x64 clock = 153.6 kHz

### RxD<sub>DATA</sub> [Receive Data]

The μPD71051 receives serial data through the RxD<sub>DATA</sub> input.

### RxRDY [Receiver Ready]

The RxRDY output becomes 1 when the μPD71051 receives one character of data and transfers that data to the receive data buffer; that is, when the receive data can be read. This signal can be used as an interrupt signal for a data read request to the CPU. You can

determine the status of RxRDY by reading bit 1 of the status byte and use the μPD71051 in a polling application. RxRDY becomes 0 when the CPU reads the receive data.

Unless the CPU reads the receive data (after RxRDY = 1 is set) before the next single character is received and transferred to the receive buffer, an overrun error occurs, and the OVE status bit is set. The unread data in the receive data buffer is overwritten by newly transferred data and lost.

RxRDY is set to 0 in the receive disable state. This state is set by changing the RxEN bit to 0 through the command byte. After RxEN is set to 1 (making receiving possible), RxRDY becomes 1 whenever new characters are received and transferred to the receive data buffer.

### SYNC/BRK [Synchronization/Break]

The SYNC pin detects synchronization characters in sync mode. The SYNC mode byte selects internal or external SYNC detection. The SYNC pin becomes an output when internal synchronization is set, and an input when external synchronization is set.

The SYNC output goes high when the μPD71051 detects a SYNC character in internal synchronization. When two SYNC characters are used, SYNC goes high when the last bit of the two consecutive SYNC characters is detected. You can read the status of the SYNC signal in bit 6 of the status byte. Both the SYNC pin and status are set to 0 by a read status operation.

In external synchronization, in order for the external circuit to detect synchronization, a high level of at least one period of R<sub>x</sub>CLK must be input to the SYNC pin. When the μPD71051 detects the high level, it begins to receive data, starting at the rising edge of the next R<sub>x</sub>CLK. The high level input may be removed when synchronization is released.

The BRK output is used only in async mode and shows the detection of a break state. BRK goes high when a low level signal is input to the RxD<sub>DATA</sub> pin for two character bit lengths (including the start, stop, and parity bits). As with SYNC, you can read the status of BRK in bit 6 of the status byte. BRK is not cleared by the read operation.

The set BRK signal is cleared when the RxD<sub>DATA</sub> pin returns to high level, or when the μPD71051 is reset by hardware or software. The SYNC/BRK pin goes low on reset, regardless of previous mode. Figure 1 shows the break state and BRK signal.

## RxCLK [Receiver Clock]

RxCLK is a reference clock input that controls the receive data rate. In sync mode, the receiving rate is the same as RxCLK. In async mode, RxCLK can be 1, 16, or 64 times the receive rate. Serial data from RxDATA is input by the rising edge of RxCLK.

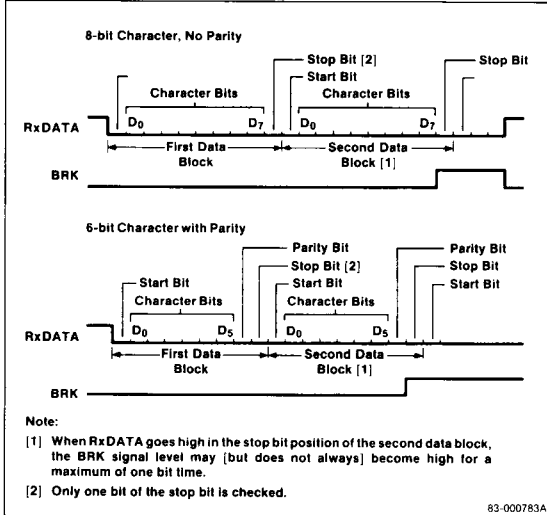
## V<sub>DD</sub> [Power]

+5 V power supply.

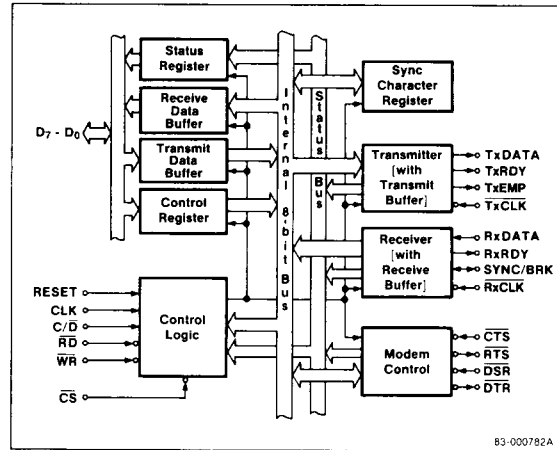
## GND [Ground]

Ground.

**Figure 1. Break Status and Break Signal**



## Block Diagram



The CPU can read the current status of the μPD71051 and can process data after checking the status, after checking for transfer errors, and μPD71051 data buffer status.

The μPD71051 can be reset under hardware or software control to a standby mode that consumes less power and removes the device from system operation. In this mode, the μPD71051's previous operating mode is released and it waits for a mode byte to set the mode. The μPD71051 leaves standby mode and shifts to a designated operating mode when the CPU writes a mode byte to it.

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## Status Register

The status register allows the CPU to read the status of the μPD71051 except in standby mode. This register indicates status and allows the CPU to manage data reading, writing, and error handling during operations.

## Receive Data Buffer

When the receiver has converted the serial data input from the RxDATA pin into parallel data, the converted data is stored in the receive data buffer. The CPU can then read it. Data for one character entering the receive buffer is transferred to the receive data buffer and RxRDY becomes 1, requesting that the CPU read the data.

## μPD71051 Functions

The μPD71051 is a CMOS serial control (USART) unit that provides serial communications in microcomputer systems. The CPU handles the μPD71051 as an ordinary I/O device.

The μPD71051 can operate in synchronous or asynchronous systems. In sync mode, the character bit length, number of sync characters, and sync detection mode must be designated. In async mode, the communication rate, character bit length, stop bit length, etc., must be designated. The parity bit may be designated in either mode.

The μPD71051 converts parallel data received from the CPU into serial transmitted data (from the TxDATA pin), and converts serial input data (from the RxDATA pin) into parallel data so that the CPU can read it (receiving operation).

## μPD71051

### Transmit Data Buffer

The transmit data buffer holds the parallel data from the CPU that the transmitter will convert to serial data and output from the TxDATA pin. When the CPU writes transmit data to the μPD71051, the μPD71051 stores data in the transmit data buffer. The transmit data buffer transfers the data to the transmitter, which sends the data from the TxDATA pin.

### Control Register

This register stores the mode and the command bytes.

### Control Logic

The control logic sends control signals to the internal blocks and controls the operation of the μPD71051 based on internal and external signals.

### Synchronous Character Register

This register stores one or two SYNC characters used in sync mode. During transmission, the SYNC characters stored in this register are output from the TxDATA pin when the CPU does not send a new character and TxEMP status is set. During receiving, synchronization is established when the characters received and the SYNC characters stored in this register are the same.

### Transmitter

The contents of the transmit data buffer are transferred to the transmitter, converted from parallel to serial, and output from the TxDATA pin. The transmitter adds start, stop, and parity bits.

### Receiver

The receiver converts serial data input from the RxDATA pin into parallel data and transfers the parallel data to the receive data buffer, allowing the CPU to read it.

The receiver detects SYNC characters and checks parity bits in sync mode. It detects the start and stop bits, and checks parity in the async mode.

In async mode, receiving does not begin (the start bit is not detected) until one effective stop bit (high level) is input to the RxDATA pin and Receive Enable (RxEN = 1) is set after setting up the mode.

### Modem Control

This block controls the  $\overline{\text{CTS}}$ ,  $\overline{\text{RTS}}$ ,  $\overline{\text{DSR}}$ , and  $\overline{\text{DTR}}$  modem interface pins. The  $\overline{\text{RTS}}$ ,  $\overline{\text{DSR}}$ , and  $\overline{\text{DTR}}$  pins can also be used as general-purpose I/O pins.

### Absolute Maximum Ratings

T <sub>A</sub> = +25°C	
Power supply voltage, V <sub>DD</sub>	-0.5 to +7.0 V
Input voltage, V <sub>I</sub>	-0.5 to V <sub>DD</sub> + 0.3 V
Output voltage, V <sub>O</sub>	-0.5 to V <sub>DD</sub> + 0.3 V
Operating temperature, T <sub>OP</sub>	-40°C to +85°C
Storage temperature, T <sub>STG</sub>	-65°C to +150°C
Power dissipation, P <sub>DMAX</sub>	1.0 W

**Comment:** Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of this specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### Capacitance

T<sub>A</sub> = +25°C, V<sub>DD</sub> = 0 V

Parameter	Symbol	Limits			Test Conditions
		Min	Max	Unit	
Input capacitance	C <sub>I</sub>		10	pF	f <sub>c</sub> = 1MHz Unmeasured pins returned to 0 V
I/O capacitance	C <sub>I/O</sub>		20	pF	

### DC Characteristics

T<sub>A</sub> = -40°C to +85°C, V<sub>DD</sub> = +5 V ± 10%

Parameter	Symbol	Limits			Unit	Test Conditions
		Min	Typ	Max		
Input voltage high	V <sub>IH</sub>	2.2		V <sub>DD</sub> +0.3	V	
Input voltage low	V <sub>IL</sub>	-0.5		0.8	V	
Output voltage high	V <sub>OH</sub>	0.7 × V <sub>DD</sub>			V	I <sub>OH</sub> = -400 μA
Output voltage low	V <sub>OL</sub>		0.4		V	I <sub>OL</sub> = 2.5 mA
Input leakage current high	I <sub>LIH</sub>		10		μA	V <sub>I</sub> = V <sub>DD</sub>
Input leakage current low	I <sub>LIL</sub>		-10		μA	V <sub>I</sub> = 0 V
Output leakage current high	I <sub>LOH</sub>		10		μA	V <sub>O</sub> = V <sub>DD</sub>
Output leakage current low	I <sub>LOL</sub>		-10		μA	V <sub>O</sub> = 0 V
Supply current μPD71051	I <sub>DD1</sub>		10		mA	Normal mode
	I <sub>DD2</sub>		50	100	μA	Stand-by mode
μPD71051-10	I <sub>DD1</sub>		10		mA	Normal mode
	I <sub>DD2</sub>		2	50	μA	Stand-by mode

## AC Characteristics

$T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ,  $V_{DD} = 5\text{ V} \pm 10\%$

Parameter	Symbol	8 MHz Limits		10 MHz Limits		Unit	Test Conditions
		Min	Max	Min	Max		
<b>Read Cycle</b>							
Address setup to $\overline{\text{RD}} \downarrow$	$t_{\text{SAR}}$	0		0		ns	$\overline{\text{CS}}, \text{C}/\overline{\text{D}}$
Address hold from $\overline{\text{RD}} \uparrow$	$t_{\text{HRA}}$	0		0		ns	$\overline{\text{CS}}, \text{C}/\overline{\text{D}}$
$\overline{\text{RD}}$ low level width	$t_{\text{RRL}}$	150		95		ns	
Data delay from $\overline{\text{RD}} \downarrow$	$t_{\text{DRD}}$		120		85	ns	$C_L = 150\text{ pF}$
Data float from $\overline{\text{RD}} \uparrow$	$t_{\text{FRD}}$	10	80	10	65	ns	
Port ( $\overline{\text{DSR}}, \overline{\text{CTS}}$ ) set-up to $\overline{\text{RD}} \downarrow$	$t_{\text{SPR}}$	20		20		$t_{\text{CYK}}$	
<b>Write Cycle</b>							
Address setup to $\overline{\text{WR}} \downarrow$	$t_{\text{SAW}}$	0		0		ns	$\overline{\text{CS}}, \text{C}/\overline{\text{D}}$
Address hold from $\overline{\text{WR}} \uparrow$	$t_{\text{HWA}}$	0		0		ns	$\overline{\text{CS}}, \text{C}/\overline{\text{D}}$
$\overline{\text{WR}}$ low level width	$t_{\text{WWL}}$	150		95		ns	
Data setup to $\overline{\text{WR}} \uparrow$	$t_{\text{SDW}}$	80		80		ns	
Data hold from $\overline{\text{WR}} \uparrow$	$t_{\text{HWD}}$	0		0		$t_{\text{CYK}}$	
Port ( $\overline{\text{DTR}}, \overline{\text{RTS}}$ ), delay from $\overline{\text{WR}} \uparrow$	$t_{\text{DWP}}$		8		8	$t_{\text{CYK}}$	
Write recovery time	$t_{\text{RV}}$	6		6		$t_{\text{CYK}}$	Mode initialize
		8		8		$t_{\text{CYK}}$	Async mode
		16		16		$t_{\text{CYK}}$	Sync mode
<b>Serial Transfer Timing</b>							
CLK cycle time	$t_{\text{CYK}}$	125	DC	100	DC	ns	
CLK high level width	$t_{\text{KHH}}$	50		35		ns	
CLK low level width	$t_{\text{KLL}}$	35		25		ns	
CLK rise time	$t_{\text{KR}}$	5	20	5	20	ns	
CLK fall time	$t_{\text{KF}}$	5	20	5	20	ns	
TxDATA delay from TxCLK	$t_{\text{DTKTD}}$		0.5		0.5	$\mu\text{s}$	
Transmitter input clock pulse width low level	$t_{\text{TKTKL}}$	12		12		$t_{\text{CYK}}$	1xBR (Note 1)
		1		1		$t_{\text{CYK}}$	16x, 64xBR
Transmitter input clock pulse width high level	$t_{\text{TKTKH}}$	15		15		$t_{\text{CYK}}$	1xBR
		3		3		$t_{\text{CYK}}$	16x, 64xBR
Transmitter input clock frequency	$f_{\text{TK}}$ (Note 2)	DC	240	DC	300	kHZ	1xBR
		DC	1536	DC	1920	kHZ	16xBR
		DC	1536	DC	1920	kHZ	64xBR
Receiver input clock pulse width low level	$t_{\text{RKRKL}}$	12		12		$t_{\text{CYK}}$	1xBR
		1		1		$t_{\text{CYK}}$	16x, 64xBR
Receiver input clock pulse width high level	$t_{\text{RKRKH}}$	15		15		$t_{\text{CYK}}$	1xBR
		3		3		$t_{\text{CYK}}$	16x, 64xBR

**AC Characteristics (cont)**

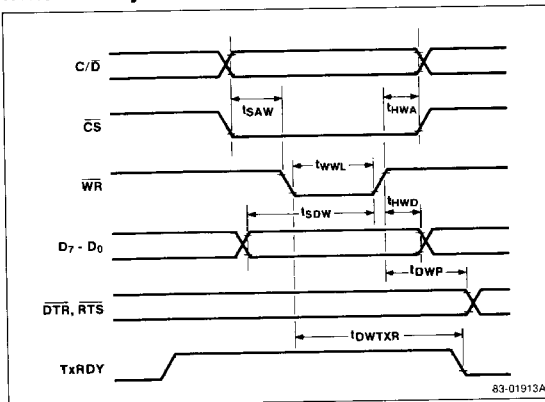
Parameter	Symbol	8 MHz Limits		10 MHz Limits		Unit	Test Conditions
		Min	Max	Min	Max		
<b>Serial Transfer Timing (cont)</b>							
Receiver input clock frequency	f <sub>RK</sub> (Note 2)	DC	240	DC	300	kHz	1xBR
		DC	1536	DC	1920		16xBR
		DC	1536	DC	1920		64xBR
RxDATA set-up to Sampling pulse	t <sub>SRDSP</sub>	1		1		μs	
RxDATA hold from sampling pulse	t <sub>HSPRD</sub>	1		1		μs	
TxEMP delay time (TxDATA)	t <sub>DTXEP</sub>		20		20	t <sub>CYK</sub>	
TxRDY delay time (TxRDY↑)	t <sub>DTXR</sub>		8		8	t <sub>CYK</sub>	
TxRDY delay time (TxRDY↓)	t <sub>DWTXR</sub>		200		100	ns	
RxRDY delay time (RxRDY↑)	t <sub>DRXR</sub>		26		26	t <sub>CYK</sub>	
RxRDY delay time (RxRDY↓)	t <sub>DRRXR</sub>		200		100	ns	
SYNC output delay time (for internal sync)	t <sub>DRKSY</sub>		26		26	t <sub>CYK</sub>	
SYNC input set-up time (for external sync)	t <sub>SSYRK</sub>	18		18		t <sub>CYK</sub>	
RESET pulse width		6		6		t <sub>CYK</sub>	

**Notes:**

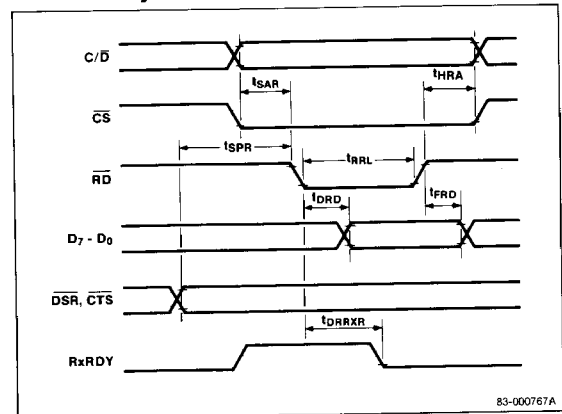
- (1) BR = Baud rate
- (2) 1xBR: f<sub>TK</sub> or f<sub>RK</sub> ≤ 1/30 t<sub>CLK</sub>, 16x, 64xBR: f<sub>TK</sub> or f<sub>RK</sub> ≤ 1/4.5 t<sub>CLK</sub>
- (3) System CLK is needed during reset operation
- (4) Status update can have a maximum delay of 28 t<sub>CYK</sub> from the event effecting the status.

**Timing Waveforms**

**Write Data Cycle**



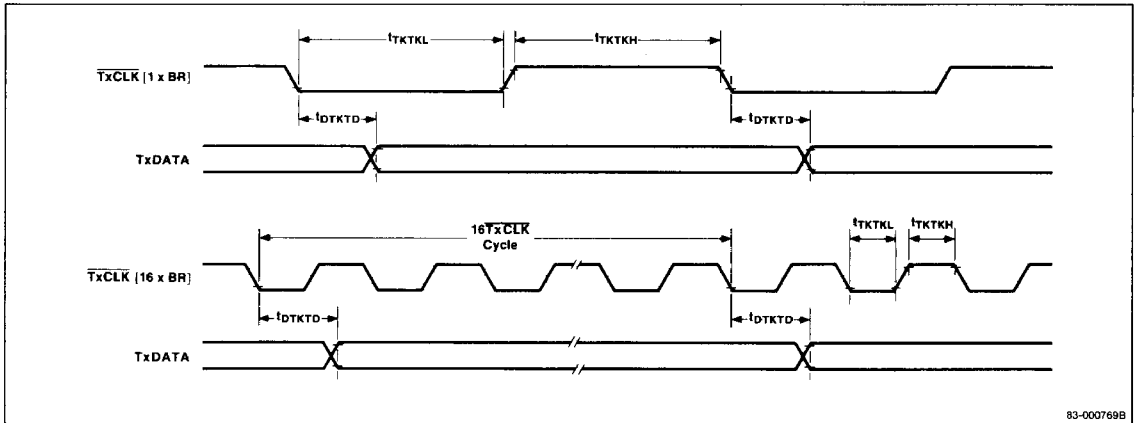
**Read Data Cycle**





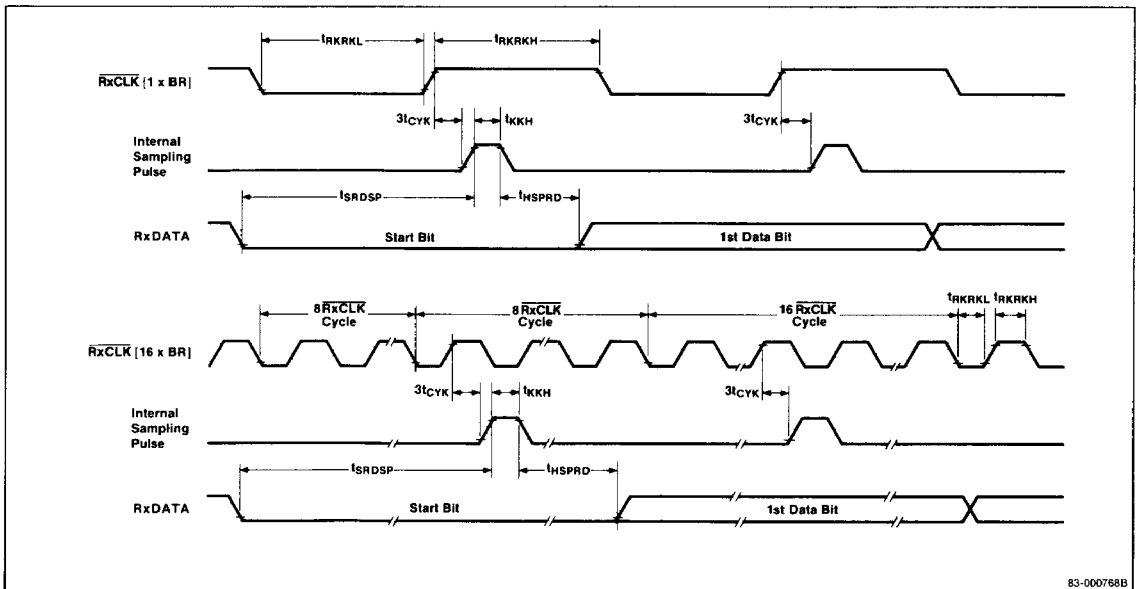
## Timing Waveforms (cont)

### Transmitter Clock and TxDATA



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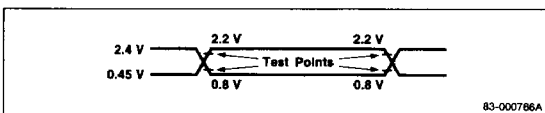
### Receiver Clock and RxDATA Timing



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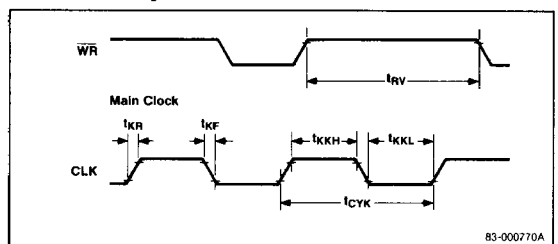
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### AC Test Input



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### Write Recovery Time



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## μPD71051

### Connecting the μPD71051 to the System

The CPU uses the μPD71051 as an I/O device by allocating two I/O addresses, set by the value of C/D̄. One I/O address is allocated when the level of C/D̄ is low and becomes a port to the transmit and receive data register. The other I/O address is allocated when C/D̄ is high and becomes a port to the mode, command, and status registers. Generally, the least significant bit (A<sub>0</sub>) of the CPU address bus is connected to C/D̄ to get a continuous I/O address. This is shown in figure 2.

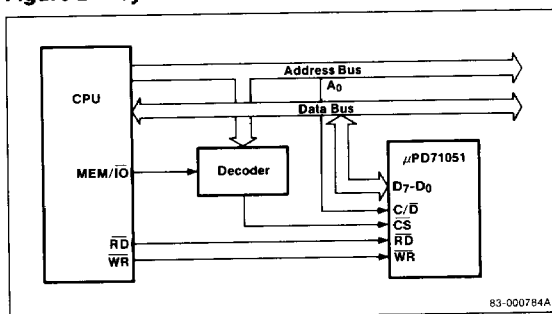
Pins TxRDY and RxRDY are connected to the CPU or, when interrupts are used, to the interrupt pin of the interrupt controller.

### Operating the μPD71051

Start with a hardware reset (set the RESET pin high) after powering on the μPD71051. This puts the μPD71051 into standby mode and it waits for a mode byte. In async mode, the μPD71051 is ready for a command byte after the mode byte; the mode byte sets the communication protocol to the async mode. In sync mode, the μPD71051 waits for one or two SYNC characters to be sent after the mode byte; set C/D̄ = 1. A command byte may be sent after the SYNC characters are written. Figure 3 shows this operation sequence.

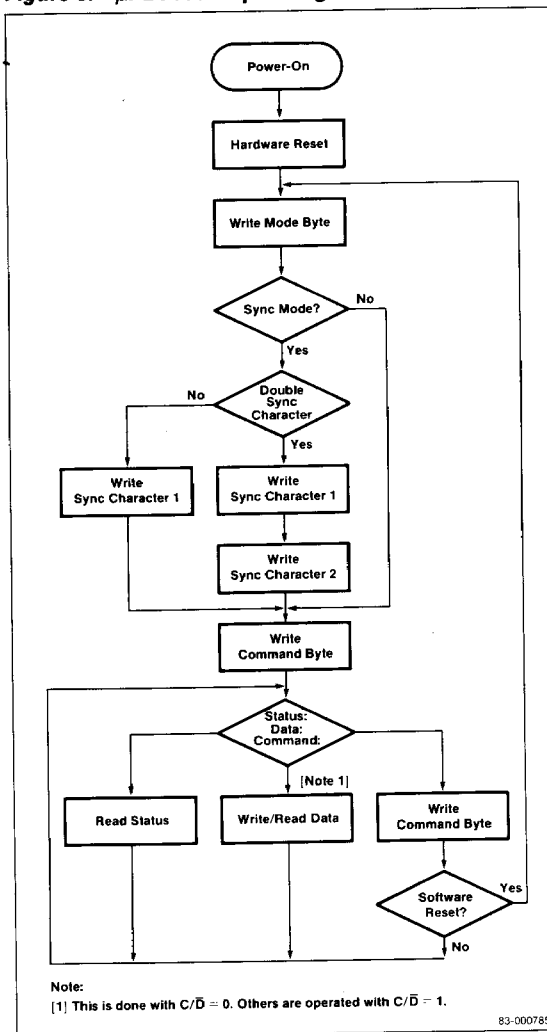
In both modes, it is possible to write transmit data, read receive data, read status, and write more command bytes after the first command byte is written. The μPD71051 performs a reset, enters standby mode, and returns to a state where it waits for a mode byte when the command byte performs a software reset.

Figure 2. System Connection



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Figure 3. μPD71051 Operating Procedure



Note:

[1] This is done with C/D̄ = 0. Others are operated with C/D̄ = 1.

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## Mode Register

When the μPD71051 is in standby mode, writing a mode byte to it will release standby mode. Figure 4 shows the mode byte format for designating async mode. Figure 5 shows the mode byte format for designating sync mode. Bits 0 and 1 must be 00 to designate sync mode. Async mode is designated by all other combinations of bits 0 and 1.

The P1, P0 and L1, L0 bits are common to both modes. Bits P1 and P0 (parity) control the generation and checking (sending and receiving) functions. These parity bit functions do not operate when P0 = 0. When P1, P0 = 01, the μPD71051 generates and checks odd parity. When P1, P0 = 11, it generates and checks even parity.

Bits L1 and L0 set the number of bits per character (n). Additional bits such as parity bits are not included in this number. Given n bits, the μPD71051 receives the number n bits of the 8-bit data written by the CPU. The upper bits (8 - n) of data that the CPU reads from the μPD71051 are set to zero.

The ST1, ST0 and B1, B0 bits are used in async mode. The ST1 and ST0 bits determine the number of stop bits added by the μPD71051 during transmission.

The B1 and B0 bits determine the relationship between the baud rates for sending and receiving, and the clocks TxCLK and RxCLK. B1 and B0 select a multiplication rate of 1, 16, or 64 for the frequency of the sending and receiving clock relative to the baud rate. Multiplication by 1 is not normally used in async mode. Note that the data and clock must be synchronized on the sending and receiving sides when multiplication by 1 is used.

The SSC and EXSYNC bits are used in sync mode. The SSC bit determines the number of SYNC characters. SSC = 1 designates one SYNC character. SSC = 0 designates two SYNC characters. The number of SYNC characters determined by the SSC bit are written to the μPD71051 immediately after writing the mode byte.

The EXSYNC bit determines whether sync detection during receiving operations is internal or external. EXSYNC = 1 selects external sync detection and EXSYNC = 0 selects internal sync detection.

Figure 4. Mode Byte for Setting Asynchronous Mode

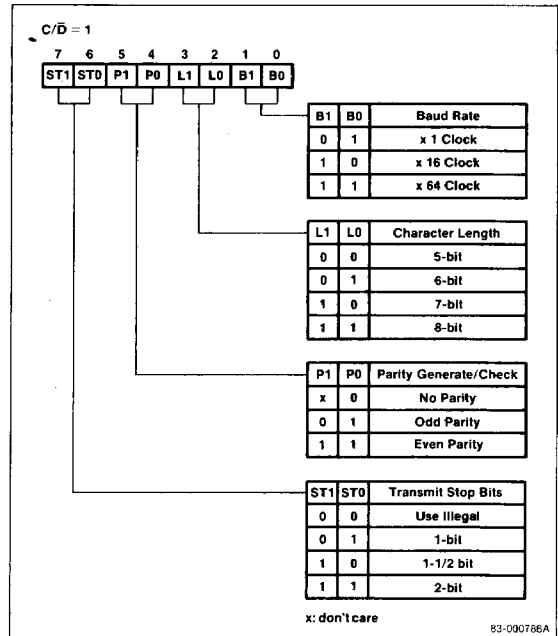
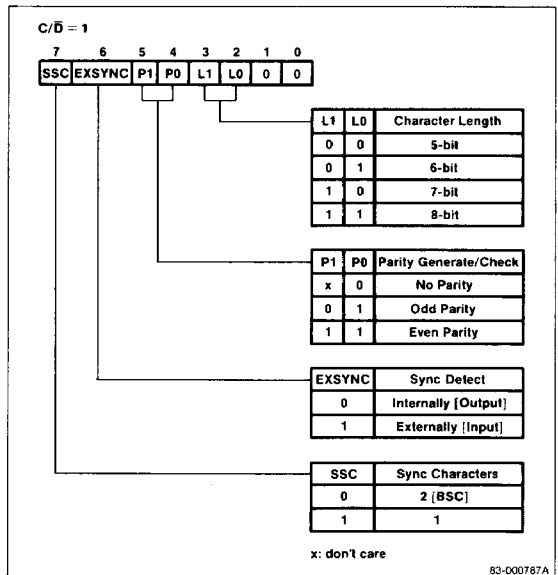


Figure 5. Mode byte for Setting Synchronous Mode



### Command Register

Commands are issued to the μPD71051 by the CPU by command bytes that control the sending and receiving operations of the μPD71051. A command byte is sent after the mode byte (in sync mode, a command byte may only be sent after writing SYNC characters) and the CPU must set  $C/\bar{D} = 1$ . Figure 6 shows the command byte format.

Bit EH is set to 1 when entering hunt phase to synchronize in sync mode. Bit RxEN should also be set to 1 at that time. Data reception begins when SYNC characters are detected and synchronization is achieved, thus releasing hunt phase.

When bit SRES is set to 1, a software reset is executed, and the μPD71051 goes into standby mode and waits for a mode byte.

Bit RTS controls the  $\overline{RTS}$  output pin.  $\overline{RTS}$  is low when the RTS bit = 1, and goes high when RTS = 0.

Setting bit ECL to 1 clears the error flags (PE, OVE, and FE) in the status register. Set ECL to 1 when entering the hunt phase or enabling the receiver.

Bit SBRK sends a break. When SBRK = 1, the data currently being sent is destroyed and the TxDATA pin goes low. Set SBRK = 0 to release a break. Break also works when TxEN = 0 (send disable).

Bit RxEN enables and disables the receiver. RxEN = 1 enables the receiver and RxEN = 0 disables the receiver. Synchronization is lost if RxEN = 0 during sync mode.

Bit DTR controls the  $\overline{DTR}$  output pin.  $\overline{DTR}$  goes low when the DTR bit = 1 and goes high when the DTR bit = 0.

The TxEN bit enables and disables the transmitter. TxEN = 1 enables the transmitter and TxEN = 0 disables the transmitter. When TxEN = 0, sending stops and the TxDATA pin goes high (mark status) after all the currently written data is sent.

### Status Register

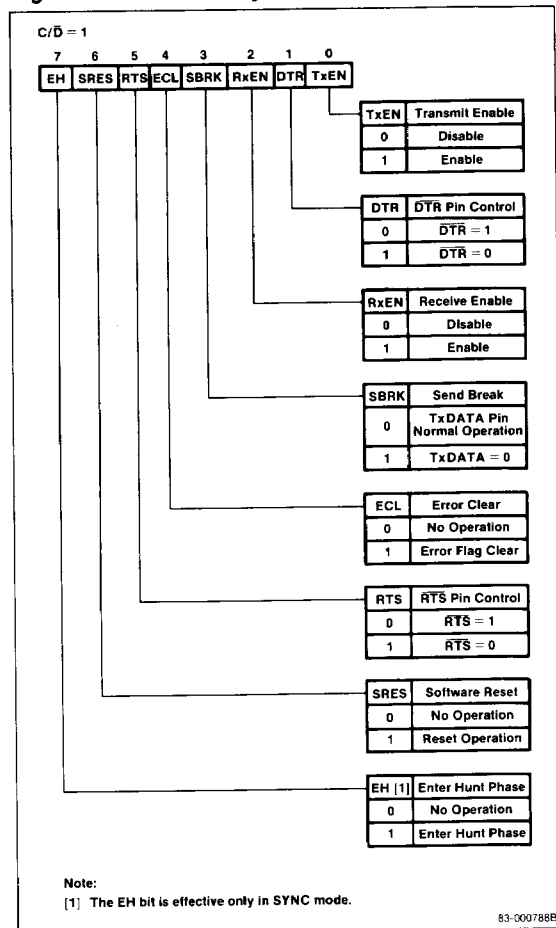
The CPU can read the status of the μPD71051 at any time except when the μPD71051 is in standby mode. Status can be read after setting  $C/\bar{D} = 1$  and  $\bar{RD} = 0$ . Status is not updated while being read. Status updating is delayed at least 28 clock periods after an event that affects the status. Figure 7 shows the format of the status register.

The TxEMP and RxRDY bits have the same meaning as the pins of the same name. The SYNC/BRK bit generally has the same meaning as the SYNC/BRK pin. In external synchronization mode, the status of this bit does not always coincide with the pin. In this case, the SYNC pin becomes an input and the status bit goes to 1 when a rising edge is detected at the input. The status bit remains at 1 until it is read, even when the input level at the SYNC pin goes low. The status bit becomes 1 when a SYNC character is input with the RxDATA input, even when the pin is at a low level.

The DSR bit shows the status of the  $\overline{DSR}$  input pin. The status bit is 1 when the DSR pin is low.

The FE bit (framing error) becomes 1 when less than one stop bit is detected at the end of each data block during asynchronous receiving. Figure 8 shows how a framing error can happen.

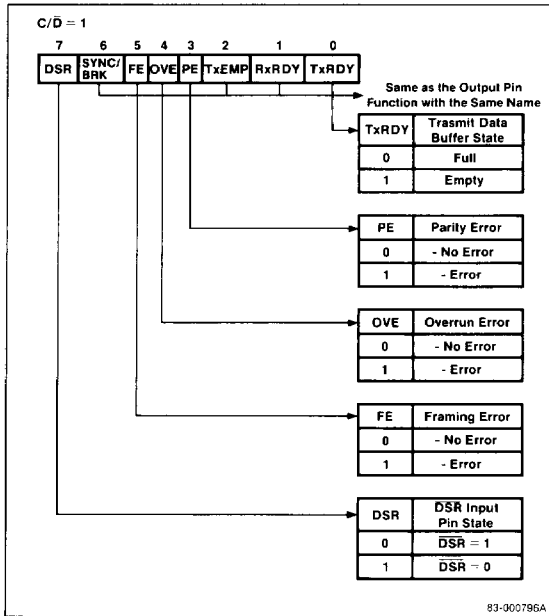
Figure 6. Command Byte Format



The OVE bit (overrun error) becomes 1 when the CPU delays reading the received data and two new data bytes have been received. In this case, the first data byte received is overwritten and lost in the receive data buffer. Figure 9 shows how an overrun can happen.

The PE bit (parity error) becomes 1 when a parity error occurs in a receive state.

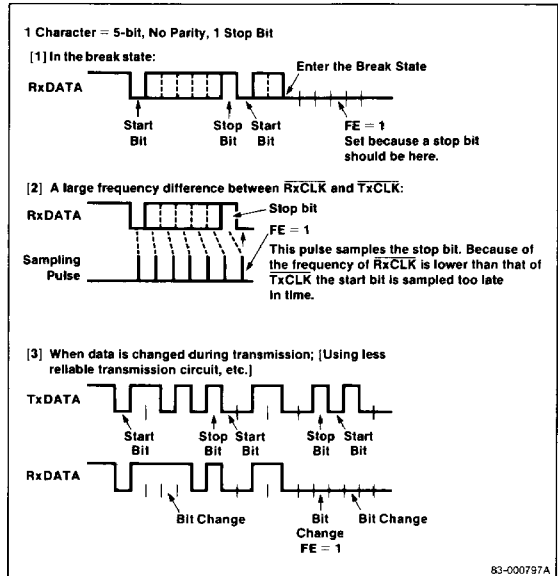
**Figure 7. Status Register Format**



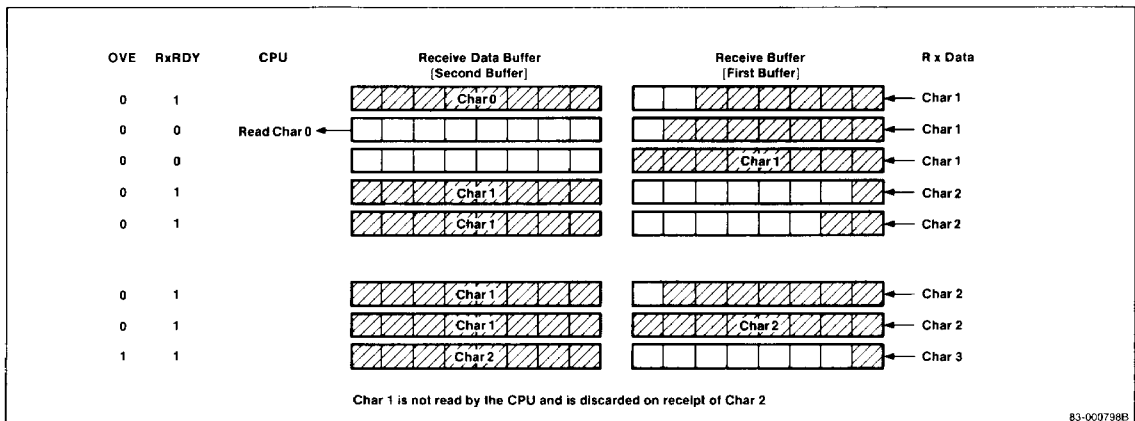
Framing, overrun, and parity errors do not disable the μPD71051's operations. All three error flags are cleared to 0 by a command byte that sets the ECL bit to 1.

The TxRDY bit becomes 1 when the transmit data buffer is empty. The TxRDY output pin becomes 1 when the transmit data buffer is empty, the CTS pin is low, and TxEN = 1. That is, bit TxRDY = Transmit Data Buffer Empty, pin TxRDY = (Transmit Data Buffer Empty) • (CTS = 0) • (TxEN = 1).

**Figure 8. Framing Error**



**Figure 9. Overrun Error**

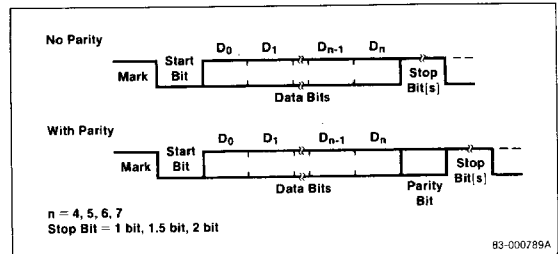


### Sending in Asynchronous Mode

The TxDATA pin is typically in the high state (marking) when data is not being sent. When the CPU writes transmit data to the μPD71051, the μPD71051 transfers the transmit data from the transmit data buffer to the send buffer and sends the data from the TxDATA pin after adding one start bit (low level) and a programmed stop bit. If parity is used, a parity bit is inserted between the character and the stop bit. Figure 10 shows the data format for async mode characters. Serial data is sent by the falling edge of the signal that divided TxCLK (1/1, 1/16, or 1/64).

When bit SBRK is set to 1, the TxDATA pin goes low (break status), regardless of whether data is being sent. Figure 11 is a fragment of a typical program to send data in the async mode. Figure 12 shows the output from pin TxDATA.

**Figure 10. Asynchronous Mode Data Format**

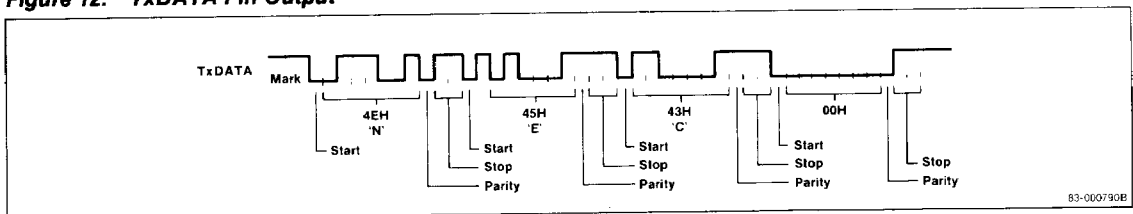


**Figure 11. Asynchronous Transmitter Example**

```

ASYNTAX :   CALL   ASYNMOD           ;Set async mode
            MOV    AL, 00010001B     ;Command: clear error flag, transmit enable
            OUT    PCTRL,AL
TXSTART :   MOV    BW, OFFSET TXDADR ;Transmit data area
            IN     AL, PCTRL
            TEST1  AL, 0              ;Read status
            BNE   TXSTART            ;Wait until TxRDY = 1
            MOV    AL, [BW]          ;Write transmit data
            OUT    PDATA, AL
            INC    BW                ;Set next data address
            CMP    AL, 00H
            BNE   TXSTART            ;End if data = 0
            RET
TXDADR     DB     'NEC'              ;Transmit data 4EH, 45H, 43H, 00
            DB     0
ASYNMOD :   MOV    AL, 0              ;Writes control bytes three times
            OUT    PCTRL, AL         ;with 00H to unconditionally
            OUT    PCTRL, AL         ;accept the new command byte
            OUT    PCTRL, AL
            MOV    AL, 01000000B     ;Software reset
            OUT    PCTRL, AL
            MOV    AL, 11111010B     ;Write mode byte
            OUT    PCTRL, AL         ;Stop bit = 2 bits, even parity
            RET                       ;7 bits/character, x16 clock
    
```

**Figure 12. TxDATA Pin Output**



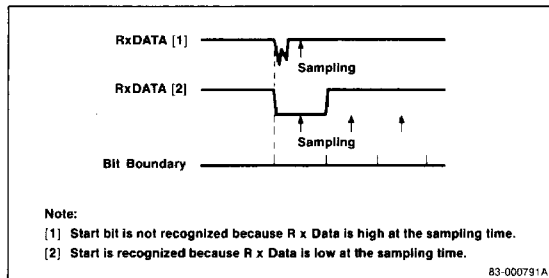
## Receiving in Asynchronous Mode

The RxDATA pin is normally in the high state when data is not being received, as shown in figure 13. The μPD71051 detects the falling edge of a low level signal when a low level signal enters it.

The μPD71051 samples the level of the RxDATA input (only when x16 or x64 clock is selected) in a position 1/2 bit time after the falling edge of the RxDATA input to check whether this low level is a valid start bit. It is considered a valid start bit if a low level is detected at that time. If a low level is not detected, it is not regarded as a start bit and the μPD71051 continues testing for a valid start bit.

When a start bit is detected, the sampling points of the data bits, parity bit (when used), and stop bit are decided by a bit counter. The sampling is performed by the rising edge of the RxCLK when an X1 clock is used. When a x16 or x64 clock is used, it is sampled at the nominal middle of RxCLK.

**Figure 13. Start Bit Detection**



Data for one character entering the receive buffer is transferred to the receive data buffer and causes RxRDY = 1, requesting that the CPU read the data. When the CPU reads the data, RxRDY becomes 0.

When a valid stop bit is detected, the μPD71051 waits for the start bit of the next data. If a low level is detected in the stop bit, a framing error flag is set; however, the receiving operation continues as if the correct high level had been detected. A parity error flag is set if a parity error is detected. An overrun error flag is set when the CPU does not read the data in time, and the next receiving data is transferred to the receive data buffer, overwriting the unread data. The μPD71051's sending and receiving operations are not affected by these errors.

If a low level is input to the RxDATA pin for more than two data blocks during a receive operation, the μPD71051 considers it a break state and the SYNC/BRK pin status becomes 1.

In async mode, the start bit is not detected until a high level of more than one bit is input to the RxDATA pin and the receiver is enabled. Figure 14 is a fragment of a typical program to receive the data sent in the previous async transmit example.

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**Figure 14. Asynchronous Receiver Example**

```

ASYNRX :   CALL   ASYNMOD           ;Set ASYNC mode
           MOV    AL, 00010100B     ;Command: clear error flag, receive
                                           ;enable

           OUT    PCTRL,AL
           MOV    BW, OFFSET RXDADR ;Data store area
RXSTART :   IN     AL, PCTRL
           TEST1  AL, 1              ;Read status
           BNE   RXSTART             ;Wait until RxRDY = 1
           IN    AL, PDATA           ;Read and store the receive data
           MOV   [BW], AL
           INC   BW                  ;Set next store address
           CMP   AL, 00H             ;End if data = 0
           BNE   RXSTART
           RET
RXDADR    DB    256 DUP             ;Reserve receive data area
    
```

### Sending in Synchronous Mode

Following the establishment of sync mode and the enabling of the transmitter, the TxDATA pin stays high until the CPU writes the first character (normally, SYNC characters). When data is written, the TxDATA pin sends one bit for each falling edge of TxCLK if the CTS pin is low. Unlike async mode, start and stop bits are not used. However, a parity bit may be set. Figure 15 shows these data formats.

Once sending begins, the CPU must write data to the μPD71051 at the same rate as that of TxCLK. If TxEMP goes to 1 because of a delay in writing by the CPU, the μPD71051 sends SYNC characters until the CPU writes data. TxEMP goes to 0 when data is written, and the data is sent as soon as transmission of SYNC characters stops.

Figure 15. Synchronous Mode Data Format

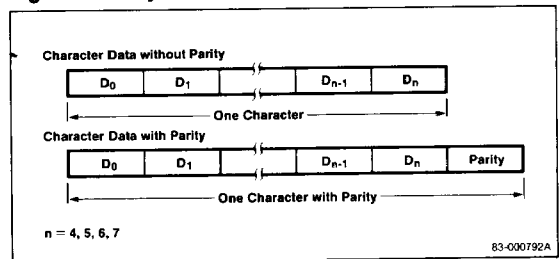


Figure 16. Synchronous Mode Transmit Timing

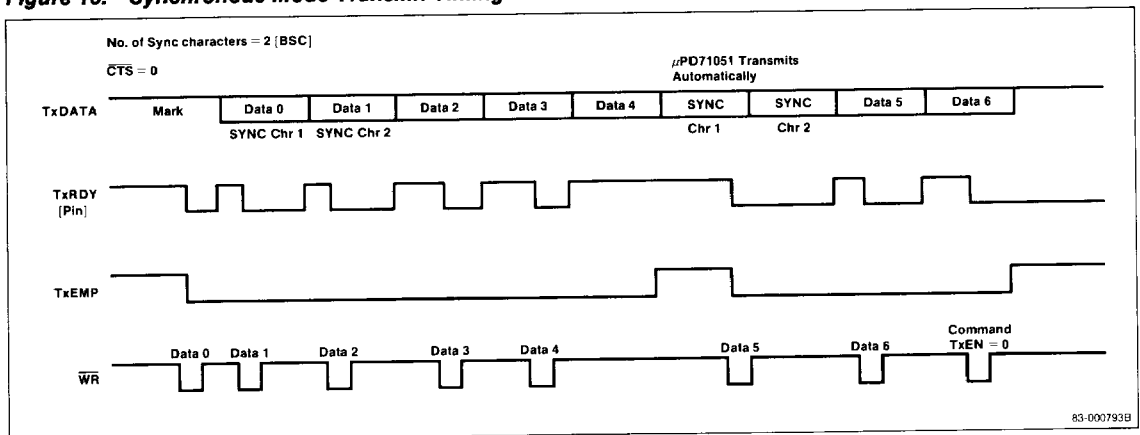
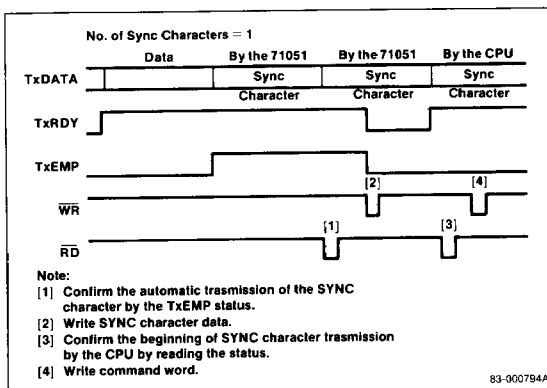


Figure 17. Issuing a Command During SYNC Character Transmission





Automatic transmission of SYNC characters begins after the CPU sends new data. SYNC characters are not automatically sent by enabling the transmitter. Figure 16 shows these timing sequences.

If a command is sent to the μPD71051 while SYNC characters are automatically being sent and TxEMP = 1, the μPD71051 may interpret the command as a data

byte and transmit it as data. If a command must be sent under these conditions, the CPU should send a SYNC character to the μPD71051 and send the command while the SYNC character is being transmitted. This is shown in figure 17.

Figure 18 is a fragment of a typical program for sending in sync mode.

**Figure 18. Synchronous Transmitter Example**

```

SYNTAX :   CALL    SYNMOD           ;Set sync mode
           MOV     AL, 00010001B    ;Command; clear error
           OUT    PCTRL, AL        ;flags, transmit enable
           MOV    BW, OFFSET TXDADR ;Start location of data area TxDADR
           MOV    CL, LDLEN         ;Set number of bytes (LDLEN) to be transmitted
           MOV    CH, 00H
TXLEN :   IN     AL, PCTRL          ;Transmit the length byte
           TEST1  AL, 0
           BZ    TXLEN
           MOV    AL, LDLEN
           OUT    PDATA, AL
TXDATA :  IN     AL, PCTRL
           TEST1  AL, 0
           BZ    TXDATA           ;Transmit the number of
           MOV    AL, (BW)         ;bytes specified by LDLEN
           OUT    PDATA, AL
           INC   BW
           DBNZ  TXDATA
           MOV    AL, 00010000B    ;Command; clear error
           OUT    PCTRL, AL        ;flags, transmit disable
           RET
SYNC1    DB     ?                 ;SYNC character 1
SYNC2    DB     ?                 ;SYNC character 2
LDLEN    DB     ?                 ;transmit data count
TXDADR   DB     255 DUP (?)       ;transmit data
SYNMOD :  MOV    AL, 00H
           OUT    PCTRL, AL        ;Write control bytes
           OUT    PCTRL, AL        ;three times with 00H to
           OUT    PCTRL, AL        ;unconditionally accept the new
           ;command byte
           MOV    AL, 01000000B    ;Software reset
           OUT    PCTRL, AL
           MOV    AL, 00111100B    ;Write mode byte: 2 SYNC
           OUT    PCTRL, AL        ;characters, internal sync detect,
           ;even parity, 8 bits/character
           MOV    AL, SYNC1
           OUT    PCTRL, AL        ;Write SYNC characters
           MOV    AL, SYNC2
           OUT    PCTRL, AL
           RET

```

### Receiving in Synchronous Mode

In order to receive in sync mode, synchronization must be established with the sending side. The first command after setting sync mode and writing the SYNC character must be EH = 1, ECL = 1, and RxEN = 1. When hunt phase is entered all the bits in the receive buffer are set to 1. In internal synchronization, data on the RxDATA pin is input to the receive buffer for each rising edge of RxCLK and is compared with the SYNC character at the same time. Figure 19 shows this internal sync detection.

When the receive buffer and the SYNC character coincide, and parity is not used, the μPD71051 ends hunt phase and SYNC is set to 1 in the center of the last SYNC bit. When parity is used, SYNC becomes 1 in the center of the parity bit. Receiving starts with the bit which follows the bit when SYNC is set to 1.

In external sync detection, synchronization is achieved by setting the SYNC pin high from an external circuit for at least one period of RxCLK. Hunt phase ends, and data reception can start. At this time, the SYNC status

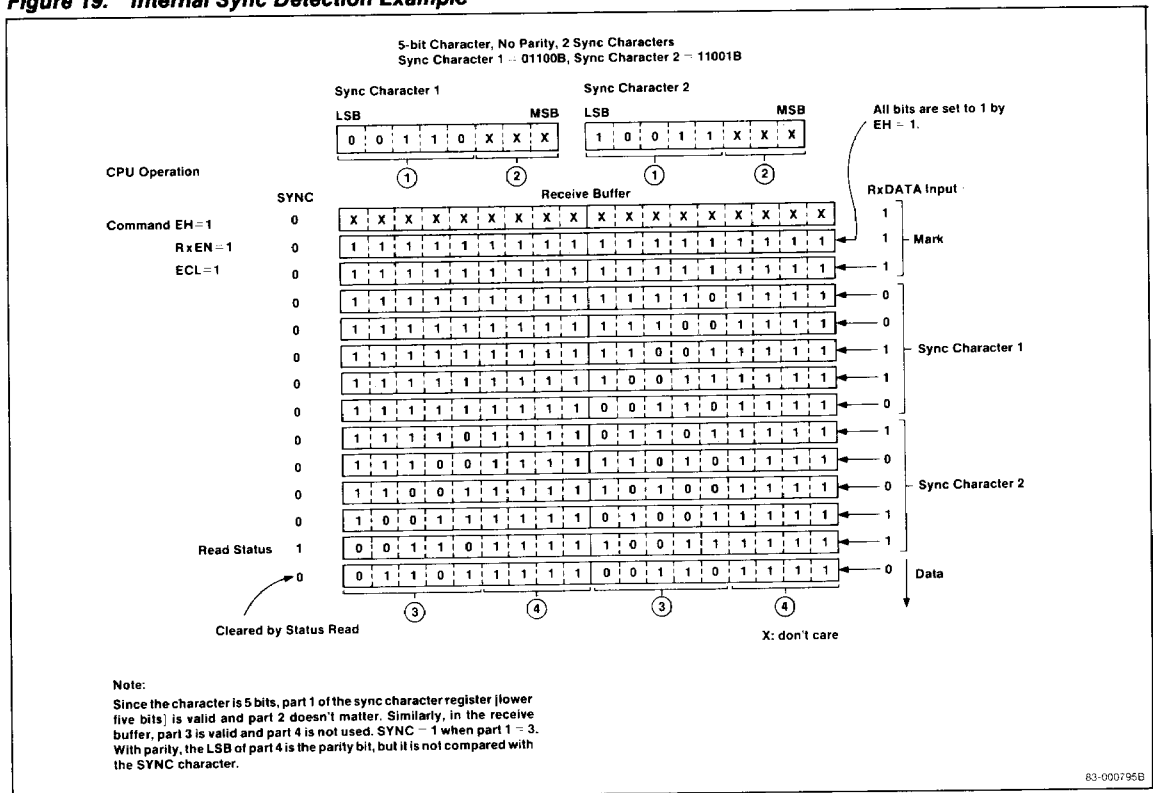
bit becomes 1, and goes to 0 when the status is read. The SYNC status bit is set to 1 when the SYNC input has a rising edge followed by a high level of more than one period of RxCLK, even after synchronization is achieved.

The μPD71051 can regain lost synchronization anytime by issuing an enter hunt phase command.

After synchronization, the SYNC character is compared with each character regardless of whether internal or external synchronization is used. When the characters coincide, SYNC becomes 1, indicating that a SYNC character has been received. SYNC (SYNC status bit only in external detection) becomes 0 when the status is read.

Overrun and parity errors are checked the same way as in async mode, affecting only the status flag. Parity checking is not performed in the hunt phase. Figure 20 is a fragment of a typical program that receives the data sent by the previous sync transmit program example. Note that the frequencies of TxCLK on the transmitter and RxCLK on the receiver must be the same.

**Figure 19. Internal Sync Detection Example**



**Figure 20. Synchronous Receiver Example**

```

SYNRX :   CALL   SYNMOD           ;Set sync mode
          MOV    AL, 10010100B    ;Command: enter hunt
          OUT    PCTRL, AL        ;phase, clear error flags, receive enable
          MOV    BW, OFFSET RXDADR ;Set receive data store address

RXLEN :   IN     AL, PCTRL
          TEST1  AL, 1
          BZ     RXLEN             ;Receive the number of
          IN     AL, DATA         ;receive data
          MOV    STLEN, AL        ;Set the number of
          MOV    CL, AL           ;receive data to both variable and
                                   ;counter

RXDATA :  MOV    CH, 00H
          IN     AL, PCTRL
          TEST1  AL, 1
          BZ     RXDATA           ;Receive and store the
          IN     AL, PDATA        ;number of data bytes
          MOV    [BW], AL         ;stated by the counter
          INC    BW
          DBNZ   RXDATA
          MOV    AL, 00000000B    ;Command: receive disable
          OUT    PCTRL, AL

STLEN    DB     ?                ;Set number of receiver data
RXDADR   DB     256 DUP (0)      ;Reserve receive data area
    
```

## Standby Mode

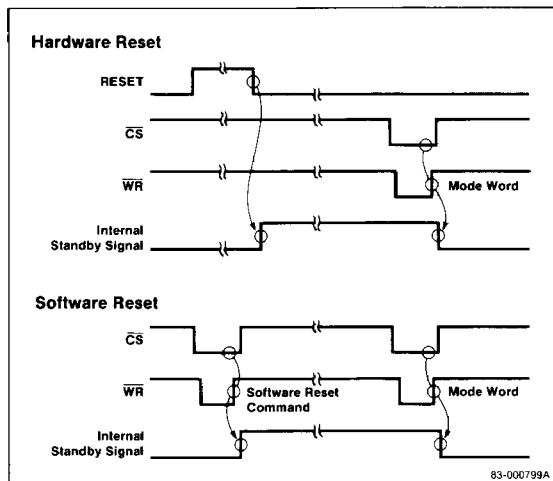
The μPD71051 is a low-power CMOS device. In standby mode, it disables the external input clocks to the inside circuitry (CLK, TxCLK, and RxCLK), thereby consuming less power.

A hardware reset is one way to enter standby mode. The input of a high level to the RESET pin causes the μPD71051 to enter standby mode at the falling edge of the high level. A software reset command is the other way to enter standby mode. The only way to take the μPD71051 out of standby mode is to write a mode byte.

In standby mode, the TxRDY, TxEMP, RxRDY, and SYNC/BRK pins are at low level and the TxDATA, DTS, and RTS pins are at high level.

Figure 21 shows the timing for standby mode. While the internal standby signal is high, the external clocks to the μPD71051 are ignored. If data (C/D = 0) is written to the μPD71051 in standby mode, the operations are undefined and unpredictable operation may result.

**Figure 21. Standby Mode Timing**



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