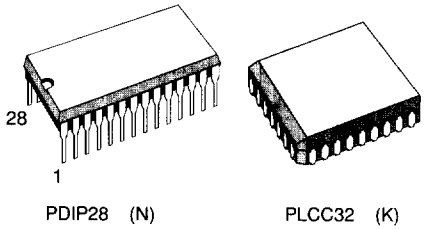
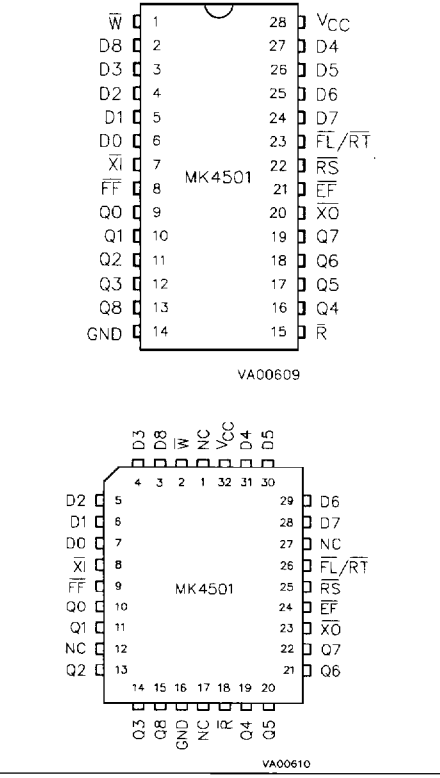
CMOS 512 x 9 BiPORT FIFO

- FIRST-IN, FIRST-OUT MEMORY BASED ARCHITECTURE
- FLEXIBLE 512 x 9 ORGANIZATION
- LOW POWER HCMOS TECHNOLOGY
- ASYNCHRONOUS AND SIMULTANEOUS READ/WRITE
- BIDIRECTIONAL APPLICATIONS
- FULLY EXPANDABLE BY WORD WIDTH OR DEPTH
- EMPTY AND FULL WARNING FLAGS
- RETRANSMIT CAPABILITY
- HIGH PERFORMANCE



PDIP28 (N) PLCC32 (K)

Figure 1. Pin Connections



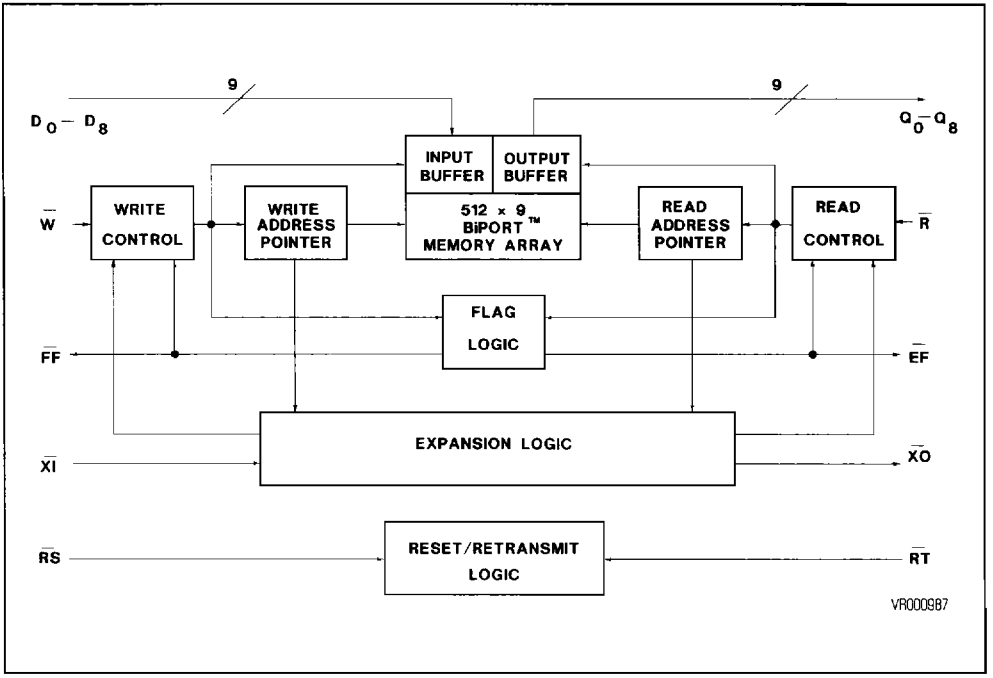
DESCRIPTION

The MK4501 is a BiPORT™ FIFO memory, which utilizes special two-port cell tech- niques. Specifically, this device implements a First-In, First-Out algorithm, featuring asynchronous read/write operations, full and empty flags, and unlimited expansion capability in both word size and depth. The main application of the MK4501 is as a rate buffer, sourcing and absorbing data at different rates, (e.g., interfacing fast processors and slow peripherals). The full and empty flags are provided to

PIN NAMES

$\overline{W}$	Write
$\overline{R}$	Read
$\overline{RS}$	Reset
D0-D8	Data Inputs
Q0-Q8	Data Outputs
GND	Ground
$\overline{XI}$	Expansion Input
$\overline{XO}$	Expansion Output
$\overline{FF}$	Full Flag
$\overline{EF}$	Empty Flag
$\overline{FL/RT}$	First Load / Retransmit
V_{CC}/GND	5 Volts/Ground
NC	Not Connected

Figure 2. Block Diagram



INTRODUCTION (Continued)

prevent data overflow and underflow. The data is loaded and emptied on a First-In, First-Out (FIFO) basis, and the latency for the retrieval of data is approximately one load cycle (write). Since the writes and reads are internally sequential, thereby requiring no address information, the pinout definition will serve this and future high-density devices. The ninth bit is provided to support control or parity functions.

FUNCTIONAL DESCRIPTION

Unlike conventional shift register based FIFOs, the MK4501 employs a memory-based architecture wherein a byte written into the device does not "ripple-through". Instead, a byte written into the MK4501 is stored at a specific location, where it remains until over-written. The byte can be read and re-read as often as desired.

Twin address pointers (ring counters) automatically generate the addresses required for each write and read operation. The empty/full flag circuit prevents illogical operations, such as reading un-written bytes (reading while empty) or over-writing un-read bytes (writing while full). Once a byte stored at a given address has been read, it can be over-written. Address pointers automatically loop back to address zero after reaching address 511. The empty/full status of the FIFO is therefore a function of the distance between the pointers, not of their absolute location. As long as the pointers do not catch one another, the FIFO can be written and read continuously without ever becoming full or empty.

Resetting the FIFO simply resets the address pointers to address zero. Pulsing retransmit resets the read address pointer without affecting the write address pointer.

With conventional FIFOs, implementation of a larger FIFO is accomplished by cascading the indi-vidual FIFOs. The penalty of cascading is often unacceptable ripple-through delays. The 4501 allows implementation of very large FIFOs with no timing penalties. The memory-based architecture of the MK4501 allows connecting the read, write, data in, and data out lines of the MK4501s in parallel. The write and read control circuits of the individual FIFOs are then automatically enabled and disabled through the expansion-in and expansion-out pins as appropriate (see the Expansion Timing section for a more complete discussion).

RECOMMENDED DC OPERATING CONDITIONS ($0°C \le T_A \le +70°C$)

Symbol	Parameter	Min.	Typ.	Max.	Unit	Notes
V_{CC}	Supply Voltage	4.5	5	5.5	V	3
GND	Ground	0	0	0	V	
V_{IH}	Logic "1" All Inputs	2.0		V_{CC} + 1	V	3
V_{IL}	Logic "0" All Inputs	–0.3		0.8	V	3, 4

DC ELECTRICAL CHARACTERISTICS ($0°C \le T_A \le +70°C$; $V_{CC} = 5V \pm 10\%$)

Symbol	Parameter	Min.	Typ.	Max.	Unit	Note
I_{IL}	Input Leakage Current (Any Input)			± 1	µA	5
I_{OL}	Output Leakage Current			± 10	µA	6
V_{OH}	Output Logic 1 Voltage (I_{OUT} = –1mA)	2.4			V	3
V_{OL}	Output Logic 0 Voltage (I_{OUT} = 4mA)			0.4	V	3
I_{CC1}	Average V_{CC} Power Supply Current			80	mA	7
I_{CC2}	Average Standby Current ($\overline{R} = \overline{W} = \overline{RS} = \overline{FL/RT} = V_{IH}$)			8	mA	7
I_{CC3}	Power Down Current (all Inputs ≥ V_{CC} – 0.2V)			500	µA	7

CAPACITANCE (T_A = 25°C, f = 1.0MHz)

Symbol	Parameter	Value			Unit	Note
		Min.	Typ.	Max.		
C_I	Capacitance on Input Pins			7	pF	
C_O	Capacitance on Output Pins			12	pF	8

Notes :

1. Pulse widths of less than minimum values are not valid.
2. Measured using output load shown in figure Output Load Circuit.
3. All voltages are referenced to ground.
4. 1.5 volt negativeundershoots are allowed for 10ns, once per cycle.
5. Measured with $0.4V \le V_{IN} \le V_{CC}$.
6. $\overline{R} \ge V_{IH}$, $0.4V \ge V_{OUT} \le V_{CC}$.
7. I_{CC} measurements are made with outputs open.
8. With output buffer deselected.

ABSOLUTE MAXIMUM RATINGS

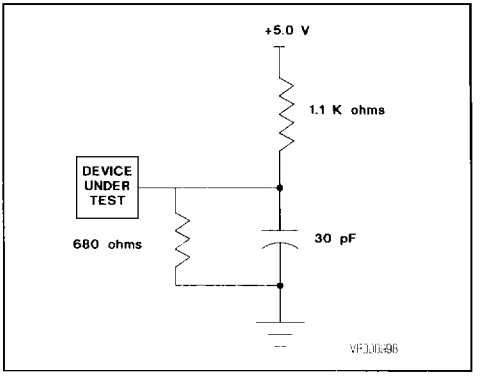
Symbol	Parameter	Value	Unit
V_I	Voltage on any Pin Relative to Ground	–0.5 to +7	V
T_A	Operating Temperature T_A (ambient)	0 to 70	°C
T_{STG}	Storage Temperature	–55 to +125	°C
P_D	Total Device Power Dissipation	1	W
I_{OUT}	Output Current per Pin	20	mA

Note : Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only, and functional operation of the device at these, or any other conditions above those indicated in the operational sections of this specification, is not implied. Exposure to absolute maximum ratings for extended periods may affect device reliability.

AC TEST CONDITIONS

Input Levels	GND to 3V
Transition Times	5ns
Input Signal Timing Reference Level	1.5V
Output Signal Timing Reference Level	0.8V and 2.2V
Ambient Temperature	0°C to 70°C
V_{CC}	5V ± 10%

Figure 3. Equivalent Output Load Circuit



READ MODE

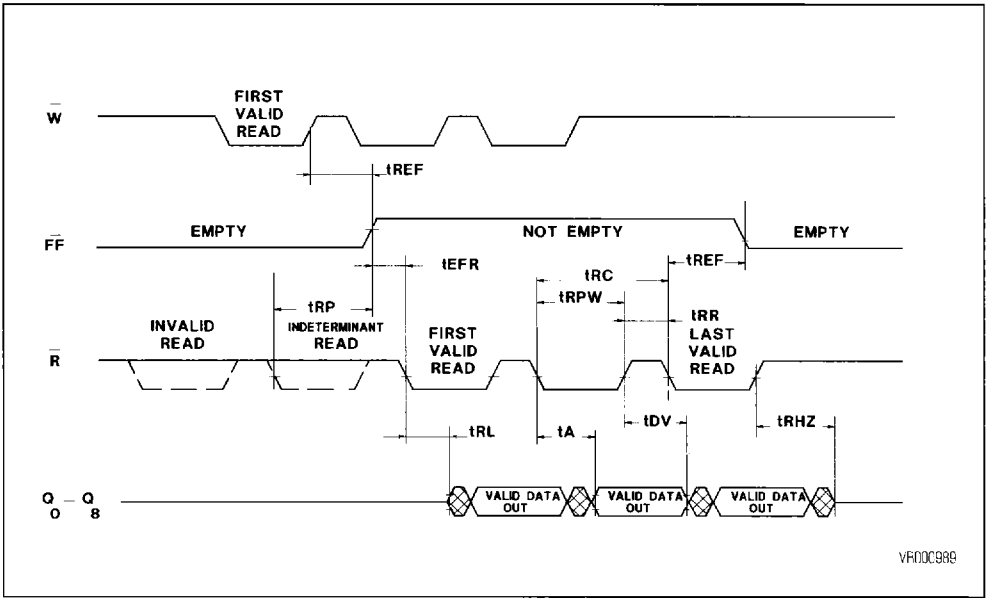
The MK4501 initiates a Read Cycle (see Figure 4a) on the falling edge of Read Enable control input ($\overline{R}$), provided that the Empty Flag ($\overline{EF}$) is not set. In the Read mode of operation, the MK4501 provides a fast access to data from 9 of 4608 locations in the static storage array. The data is accessed on a FIFO basis independent of any ongoing WRITE operations. After $\overline{R}$ goes high, data outputs will return to a high impedance condition until the next Read operation.

In the event that all data has been read from the FIFO, the $\overline{EF}$ will go low, and further Read operations will be inhibited (the data outputs will remain in high impedance). $\overline{EF}$ will go high t_{WEF} after completion of a valid Write operation. $\overline{EF}$ will again go low t_{REF} from the beginning a subsequent READ operation, provided that a second WRITE has not been completed (see figure 4B). Reads beginning t_{EFR} after $\overline{EF}$ goes high are valid. Reads begun after $\overline{EF}$ goes low and more than t_{RPI} before $\overline{EF}$ goes high are invalid (ignored). Reads beginning less than t_{RPI} before $\overline{EF}$ goes high and less than t_{EFR} later may or may not occur (be valid) depending on internal flag status.

AC ELECTRICAL CHARACTERISTICS ($0°C \le T_A \le +70°C$; $V_{CC} = +5V \pm 10\%$)

Symbol	Parameter	-65		-80		-10		-12		-15		-20		Unit	Note
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
t_{RC}	Read Cycle Time	80		100		120		140		175		235		ns	
t_A	Access Time		65		80		100		120		150		200	ns	2
t_{RR}	Read Recovery Time	15		20		20		20		25		35		ns	
t_{RPW}	Read Pulse Width	65		80		100		120		150		200		ns	1
t_{RL}	$\overline{R}$ Low to Low Z	0		0		0		0		0		0		ns	2
t_{DV}	Data Valid from High $\overline{R}$	5		5		5		5		5		5		ns	2
t_{RHZ}	$\overline{R}$ High to High Z		25		25		25		35		50		60	ns	2
t_{REF}	$\overline{R}$ Low to $\overline{EF}$ Low		60		75		95		115		145		195	ns	2
t_{EFR}	$\overline{EF}$ High to Valid Read	10		10		10		10		10		10		ns	2
t_{WEF}	$\overline{W}$ High to $\overline{EF}$ High		60		75		95		110		140		190	ns	2
t_{RPI}	Read Protect Indeterminant		35		35		35		35		35		35	ns	2

Figure 4A. Read and Empty Flag Waveforms



WRITE MODE

The MK4501 initiates a Write Cycle (see Figure 4B) on the falling edge of the Write Enable control input ($\overline{W}$), provided that the Full Flag ($\overline{FF}$) is not set. Data set-up and hold-time requirements must be satisfied with respect to the rising edge of $\overline{W}$. The data is stored sequentially and independent of any ongoing Read operations. $\overline{FF}$ is asserted during the last valid write as the MK4501 becomes full. Write operations begun with $\overline{FF}$ low are inhibited. $\overline{FF}$ will go high t_{RFF} after completion of a valid READ operation. $\overline{FF}$ will again go low t_{WFF} from the beginning of a subsequent WRITE operation, provided that a second READ has not been completed (see Figure 4A). Writes beginning t_{FFW} after $\overline{FF}$ goes high are valid. Writes beginning after $\overline{FF}$ goes low and more than t_{WPI} before $\overline{FF}$ goes high are invalid (ignored). Writes beginning less than t_{WPI} before $\overline{FF}$ goes high and less than t_{FFW} later may or may not occur (be valid), depending on internal flag status.

AC ELECTRICAL CHARACTERISTICS ($0°C \le T_A \le +70°C$; $V_{CC} = +5V \pm 10\%$)

Symbol	Parameter	-65		-80		-10		-12		-15		-20		Unit	Note
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
t_{WC}	Write Cycle Time	80		100		120		140		175		235		ns	
t_{WPW}	Write Pulse Width	65		80		100		120		150		200		ns	1
t_{WR}	Write Recovery Time	15		20		20		20		25		35		ns	
t_{DS}	Data Set Up Time	20		25		35		40		50		65		ns	
t_{DH}	Data Hold Time	10		10		10		10		10		10		ns	
t_{WFF}	$\overline{W}$ Low to $\overline{FF}$ Low		60		75		95		115		145		195	ns	2
t_{FFW}	$\overline{FF}$ High to Valid Write	10		10		10		10		10		10		ns	2
t_{RFF}	$\overline{R}$ High to $\overline{FF}$ High		60		75		95		110		140		190	ns	2

Figure 4B. Write and Full Flag Waveforms

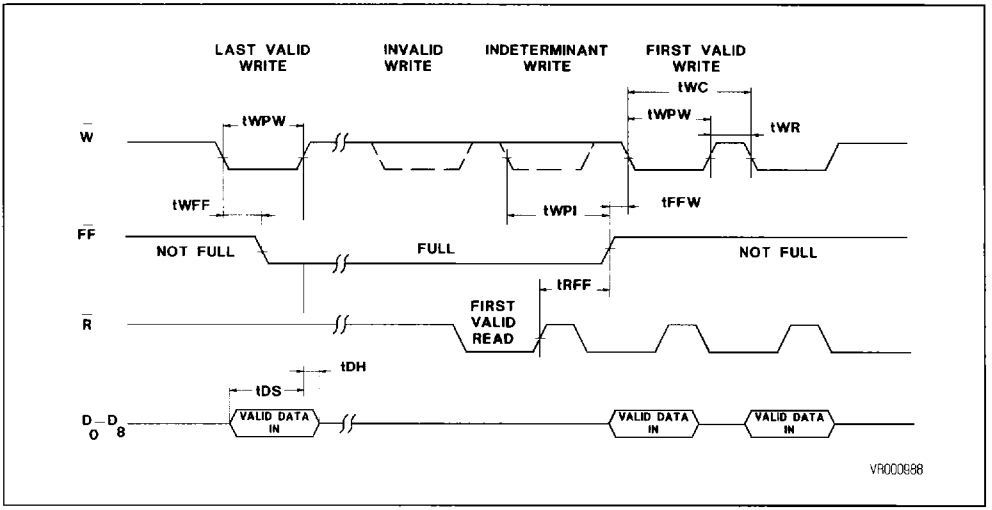


Figure 5B. Write/Read to Empty Flag Waveforms

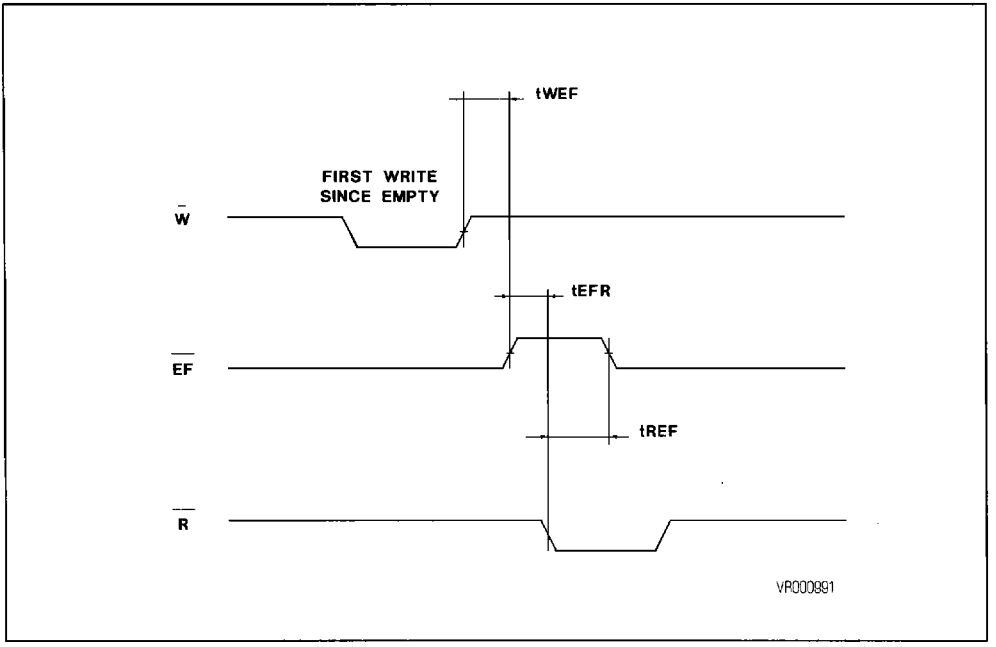
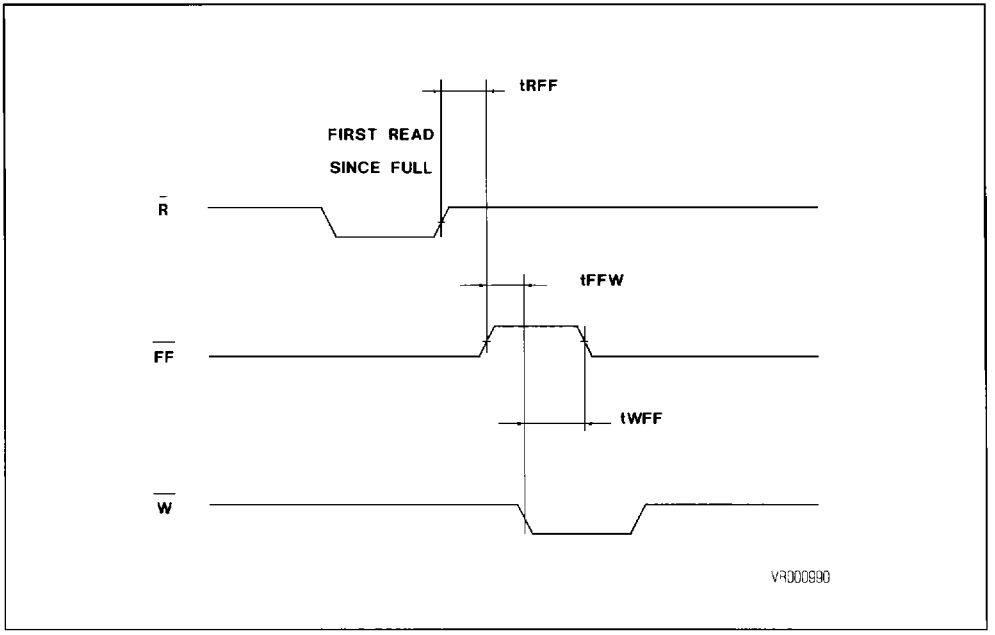


Figure 5B. Read/Write to Full Flag Waveforms



RESET

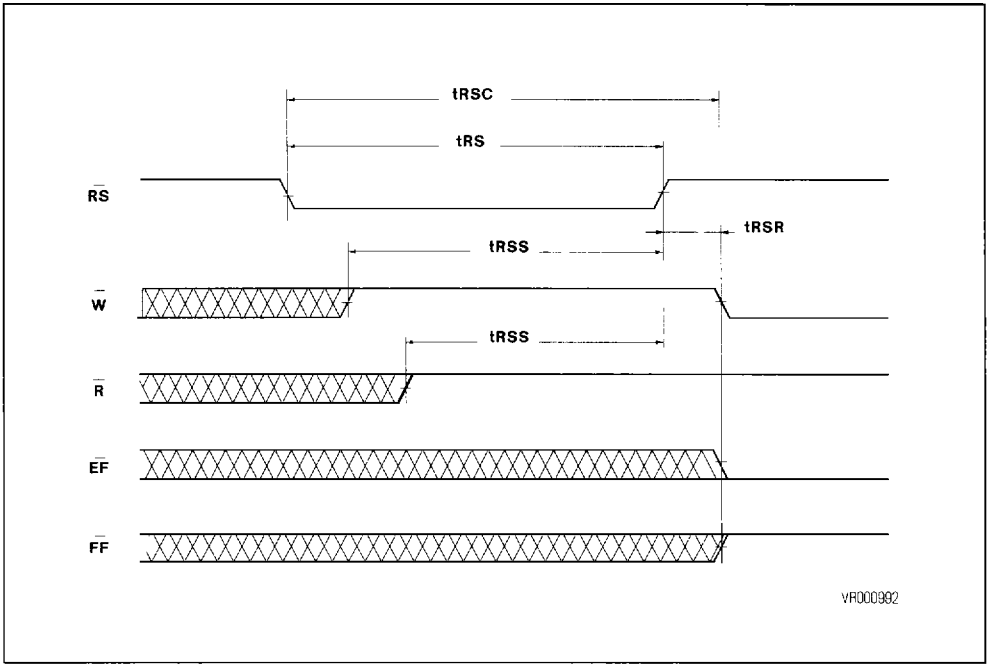
The MK4501 is reset (see Figure 6) whenever the Reset pin ($\overline{RS}$) is in the low state. During a Reset, both the internal read and write pointers are set to the first location. Reset is required after power up, before a Write operation can begin.

Although neither $\overline{W}$ or $\overline{R}$ need be high when $\overline{RS}$ goes low, both $\overline{W}$ and $\overline{R}$ must be high t_{RSS} before $\overline{RS}$ goes high, and must remain high t_{RSR} afterwards. Refer to the following discussion for the required state of $\overline{FL}/\overline{RT}$ and $\overline{XI}$ during Reset.

AC ELECTRICAL CHARACTERISTICS ($0°C \leq T_A \leq +70°C$; $V_{CC} = +5V \pm 10\%$)

Symbol	Parameter	-65		-80		-10		-12		-15		-20		Unit	Note
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
t_{RSC}	Reset Cycle Time	80		100		120		140		175		235		ns	
t_{RS}	Reset Pulse Width	65		80		100		120		150		200		ns	1
t_{RSR}	Reset Recovery Time	15		20		20		20		25		35		ns	
t_{RSS}	Reset Set Up Time	45		60		80		100		130		180		ns	

Figure 6. Reset Waveforms



Note : $\overline{EF}$ and $\overline{FF}$ may change status during Reset, but flags will be valid at t_{RSC}.

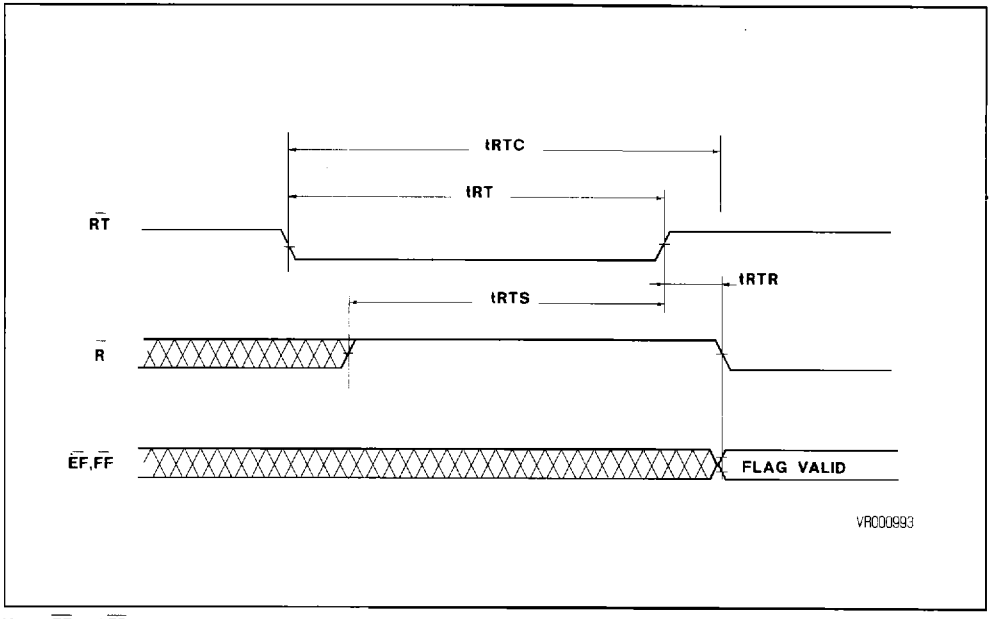
RETRANSMIT

The MK4501 can be made to retransmit (re-read previously read data) after the Retransmit pin ($\overline{RT}$) is pulsed low. (see Figure 7).

A Retransmit operation sets the internal read pointer to the first physical location in the array, but will not affect the position of the write pointer. $\overline{R}$ must be inactive t_{RTS} before $\overline{RT}$ goes high, and must remain high for t_{RTR} afterwards.

The Retransmit function is particularly useful when blocks of less than 512 Writes are performed between Resets. The Retransmit feature is not compatible with Depth Expansion.

Figure 7. Retransmit Waveforms



Note : $\overline{EF}$ and $\overline{FF}$ may change status during Retransmit, but flags will be valid at t_{RTC}.

AC ELECTRICAL CHARACTERISTICS ($0°C \leq T_A \leq +70°C$; $V_{CC} = +5V \pm 10\%$)

Symbol	Parameter	-65		-80		-10		-12		-15		-20		Unit	Note
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
t_{RTC}	Retransmit Cycle Time	80		100		120		140		175		235		ns	
t_{RT}	Retransmit Pulse Width	65		80		100		120		150		200		ns	1
t_{RTR}	Retransmit Recovery Time	15		20		20		20		25		35		ns	

SINGLE DEVICE CONFIGURATION

A single MK4501 may be used when application requirements are for 512 words or less. The MK4501 is placed in Single Device Configuration mode when the chip is Reset with the Expansion In pin ($\overline{XI}$) grounded (see Figure 8).

WIDTH EXPANSION

Word width may be increased simply by connecting the corresponding input control signals of multiple devices. Status Flags ($\overline{EF}$ and $\overline{FF}$) can be detected from any one device. Figure 9 demonstrates an 18-bit word width by using two MK4501s. Any word width can be attained by adding additional MK4501s.

Figure 8. A Single 512 x 9 FIFO Configuration

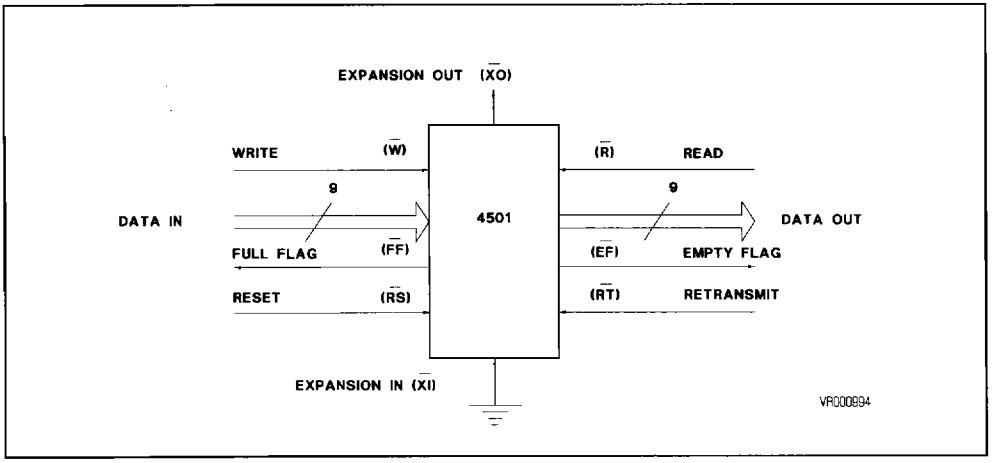
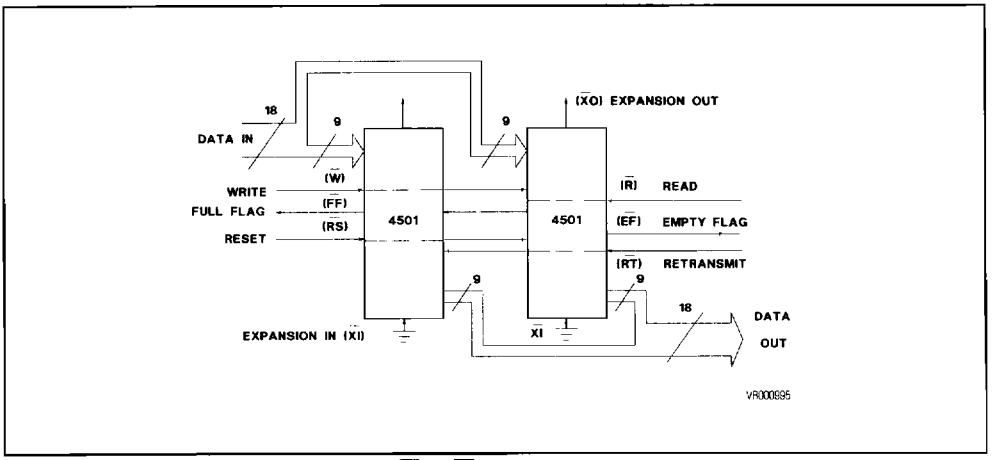


Figure 9. A 512 x 18 FIFO Configuration (Width Expansion)



Note : Flag detection is accomplished by monitoring the $\overline{FF}$ and $\overline{EF}$ signals on either (any) device used in the width expansion configuration. Do not connect flag output signals together.

DEPTH EXPANSION (Daisy Chain)

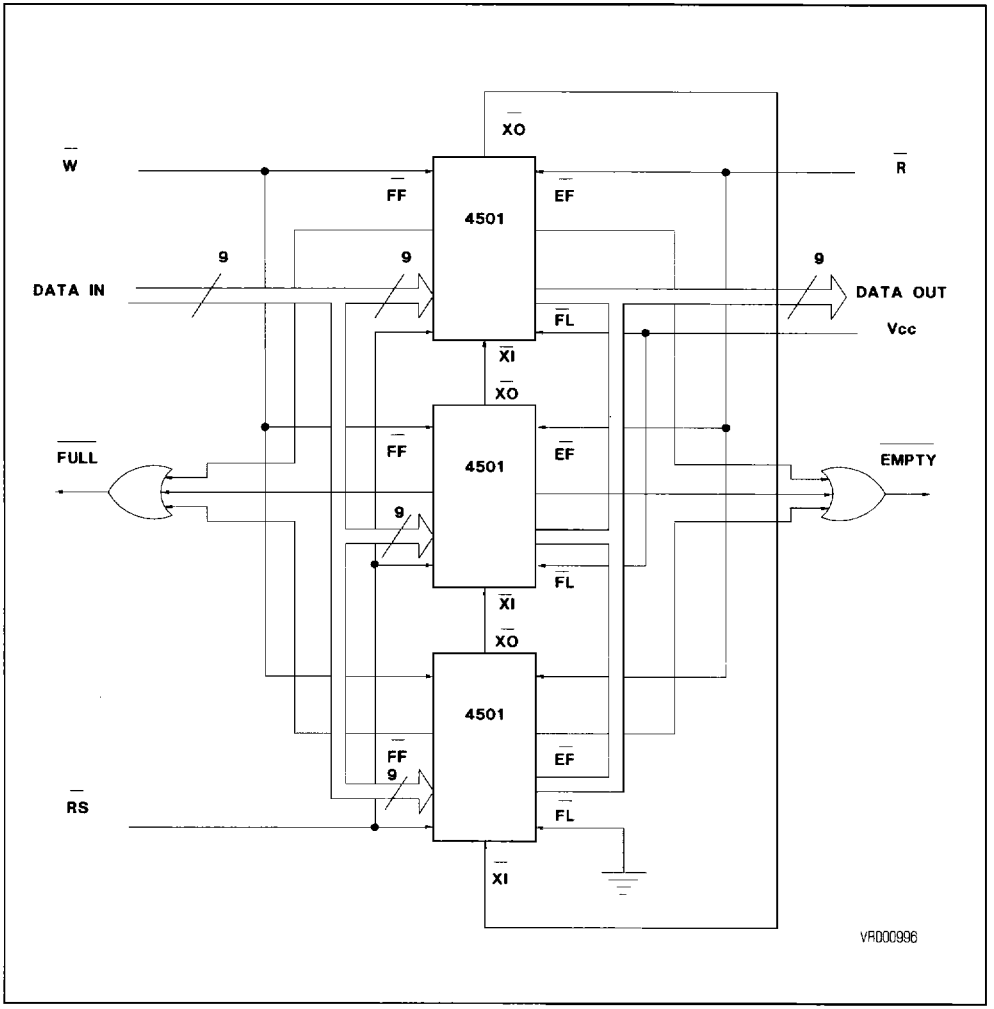
The MK4501 can easily be adapted to applications when the requirements are for greater than 512 words. Figure 10 demonstrates Depth Expansion using three MK4501s. Any depth can be attained by adding additional MK4501s.

External logic is needed to generate a composite Full Flag and Empty Flag. This requires the ORing of all $\overline{EF}$s and the ORing of all FFs (i.e., all must be set to generate the correct composite $\overline{FF}$ or $\overline{EF}$).

The MK4501 operates in the Depth Expansion configuration after the chip is Reset under the below listed conditions.

1. The first device must be designated by grounding the First Load pin ($\overline{FL}$). The Retransmit function is not valid in the Depth Expansion Mode.
2. All other devices must have $\overline{FL}$ in the high state.
3. The Expansion Out ($\overline{XO}$) pin of each device must be tied to the Expansion In ($\overline{XI}$) pin of the next device.

Figure 10. A 1536 x 9 FIFO Configuration (depth expansion)

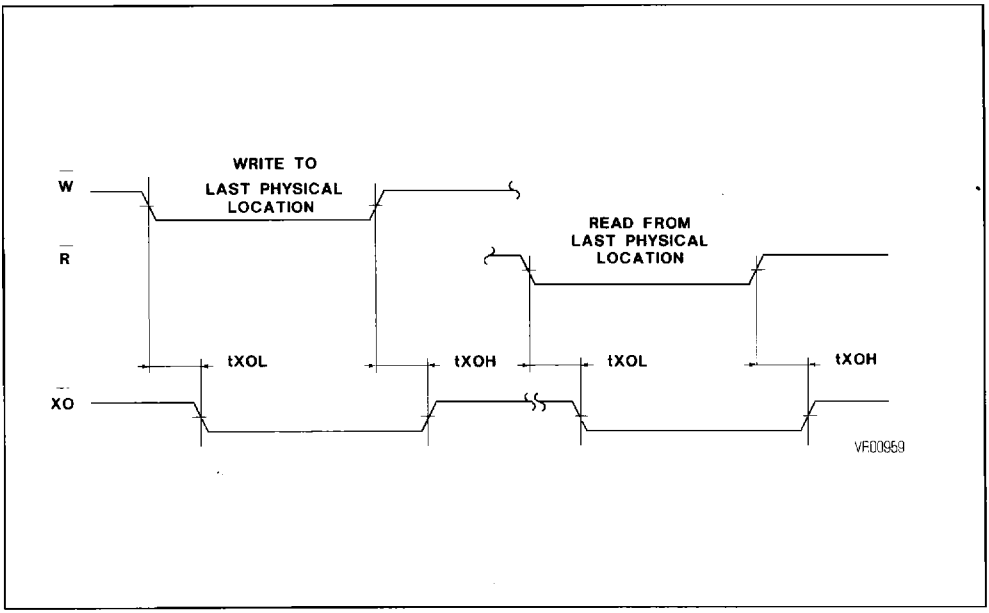


EXPANSION TIMING

Figures 11 and 12 illustrate the timing of the Expansion Out and Expansion In signals. Discussion of Expansion Out/Expansion In timing is provided to clarify how Depth Expansion works. In as much as Expansion Out pins are generally connected only to Expansion In pins, the user need not be concerned with actual timing in a normal Depth Expanded application unless extreme propagation delays exist between the $\overline{XO}/\overline{XI}$ pin pairs.

Expansion Out pulses are the image of the WRITE and READ signals that cause them ; delayed in time by t_{XOL} and t_{XOH}. The Expansion Out signal is propagated when the last physical location in the memory array is written and again when it is read (Last Read). This is in contrast to when the Full and Empty Flags are activated, which is in response to writing and reading a last available location.

Figure 11. Expansion Out Timing Waveforms

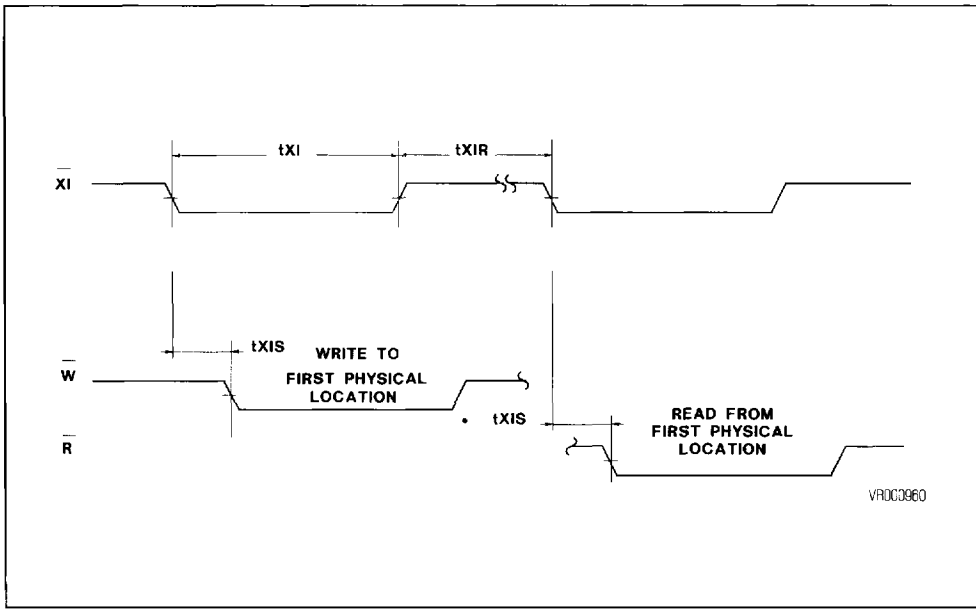


AC ELECTRICAL CHARACTERISTICS ($0°C \le T_A \le +70°C$; $V_{CC} = +5V \pm 10\%$)

Symbol	Parameter	-65		-80		-10		-12		-15		-20		Unit	Note
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
t_{XOL}	Expansion Out Low		55		70		75		90		115		150	ns	
t_{XOH}	Expansion Out High		60		80		90		100		125		155	ns	

When in Depth Expansion mode, a given MK4501 will begin writing and reading as soon as valid WRITE and READ signals begin, provided $\overline{FL}$ was grounded at RESET time. A MK4501 in Depth Expansion mode with $\overline{FL}$ high at RESET will not begin writing until after an Expansion In pulse occurs. It will not begin reading until a second Expansion In pulse occurs and the Empty Flag has gone high. Expansion In pulses must occur t_{XIS} before the WRITE and READ signals they are intended to enable. Minimum Expansion In pulse width, t_{XI}, and recovery time, t_{XIR}, must be observed.

Figure 12. Expansion In Timing Waveforms



AC ELECTRICAL CHARACTERISTICS ($0°C \leq T_A \leq +70°C$; $V_{CC} = +5V \pm 10\%$)

Symbol	Parameter	-65		-80		-10		-12		-15		-20		Unit	Note
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
t_{XI}	Expansion in Pulse Width	60		75		95		115		145		195		ns	1
t_{XIR}	Expansion In Recovery Time	15		20		20		20		25		35		ns	
t_{XIS}	Expansion In Setup Time	25		30		45		50		60		85		ns	

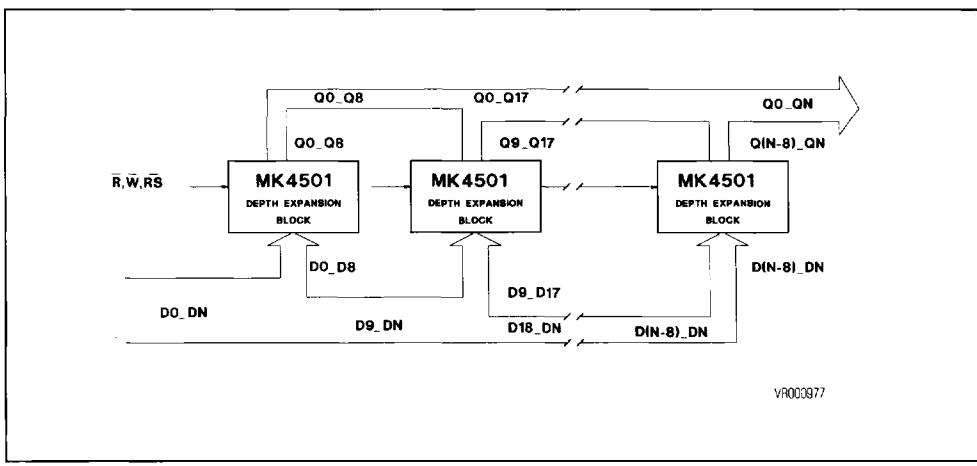
COMPOUND EXPANSION

The two expansion techniques described above can be applied together in a straight forward manner to achieve large FIFO arrays (see Figure 13).

BIDIRECTIONAL APPLICATIONS

Applications, which require data buffering between two systems (each system capable of READ and WRITE operations), can be achieved by pairing MK4501s, as shown in Figure 14. Care must be taken to ensure that the appropriate flag is monitored by each system. (i.e., $\overline{FF}$ is monitored on the device where $\overline{W}$ is used ; $\overline{EF}$ is monitored on the device where $\overline{R}$ is used). Both Depth Expansion and Width Expansion may be used in this mode.

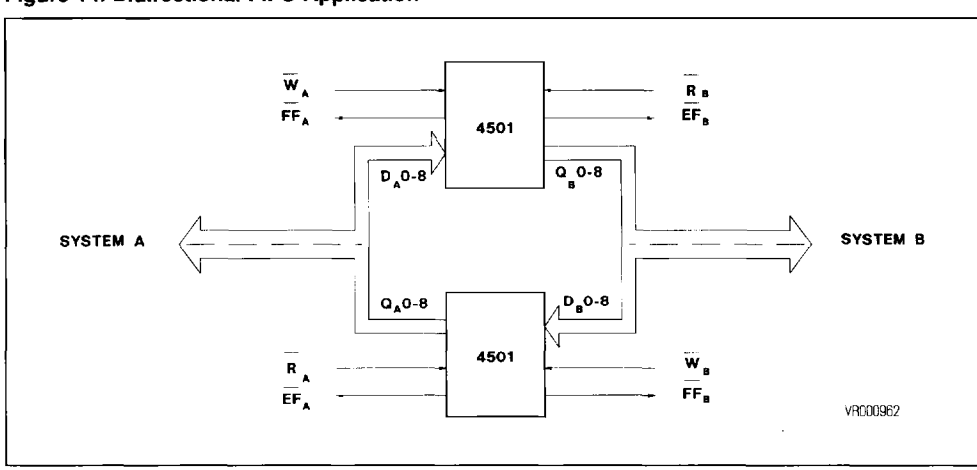
Figure 13. Compound FIFO Expansion Configuration



Notes :

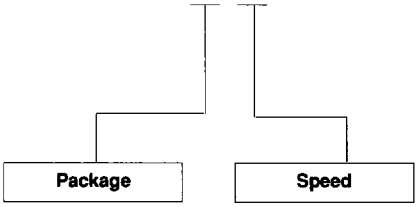
1. For depth expansion block see DEPTH EXPANSION Section and Figure 10.
2. For Flag operation see WIDTH EXPANSION Section and Figure 9.

Figure 14. Bidirectional FIFO Application



ORDERING INFORMATION

Example: MK4501 N 65



Package		Speed	
N	PDIP28	65	65ns
K	PLCC32	80	80ns
		10	100ns
		12	120ns
		15	150ns
		20	200ns

For a list of available options of Package and Speed refer to the Selector Guide in this Data Book or to the current Memory Shortform Catalogue.

For further information on any aspect of this device, please contact our Sales Office nearest you.