Calculators

MM57104 scientific calculator circuit

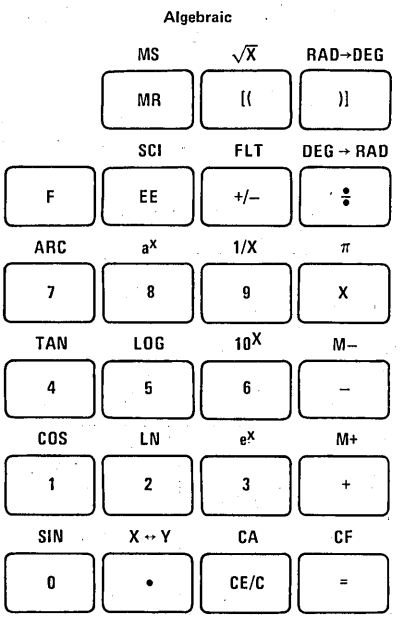
general description

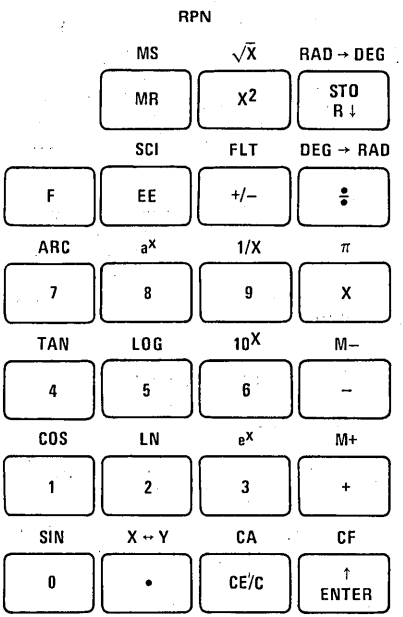
The MM57104 features the most essential and desirable scientific functions microprogrammed onto a single economical MOS/LSI device. Use of a 9-digit display with a 5-digit mantissa plus sign and a 2-digit exponent plus sign is featured even though internal numbers use a full 8-digit mantissa for accuracy. Low system cost without sacrificing features has been achieved with the MM57104; direct operation from an inexpensive throw-away 9V battery, eliminating the need for a dc/dc converter, minimal cost 23-position keyboard and a standard 9-digit low cost LED display. National's built-in reliability and rugged 24-lead DIP add further to the MM57104's total system efficiency.

features

- Enters $\pm 9.9999999 \times 10^{99}$ to $\pm 1 \times 10^{-99}$
- 9-position display: 5-digit mantissa plus sign and 2-digit exponent with sign
- Left justified entry with trailing zero suppression
- Selectable Reverse Polish Notation (RPN) or Algebraic notation with 2 levels of parentheses
- Arithmetic functions: +, −, X, ÷, 1/X, $\sqrt{X}$, X^2
- Constant operations in algebraic mode
- Power function: Y^X
- Logarithmic functions: LN X, LOG X, e^X, 10^X
- Trigonometric functions: SIN, COS, TAN, SIN^{-1}, COS^{-1}, TAN^{-1}
- Full-function, addressable memory
- 4-register working stack with ROLL capability (RPN) or EQUAL with 2 levels of parentheses (algebraic)
- π, change sign, clear, clear-all and exchange
- Auto power-on clear
- Degree/radian conversion
- Two output modes: floating or scientific

sample keyboards





absolute maximum ratings

Voltage at Any Pin Relative to V_{SS} (All Other Pins Connected to V_{SS})	V_{SS} +0.3V to V_{SS} −12V
Ambient Operating Temperature	0°C to +70°C
Ambient Storage Temperature	−55°C to +125°C
Lead Temperature (Soldering, 10 seconds)	300°C

dc electrical characteristics

$0°C \leq T_A \leq +70°C$, $7.9V \leq V_{SS} - V_{DD} \leq 9.5V$ unless otherwise stated

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Voltage ($V_{SS} - V_{DD}$)		7.0		9.5	V
Operating Supply Current (I_{DD})	$V_{SS} - V_{DD}$ = 9.5V, T_A = 25°C (Excluding Outputs)		12	18	mA
K1–K4					
Input Voltage Levels					
Logic High Level (V_{IH})	$V_{SS} - V_{DD}$ = 7.9V	V_{SS}−3.2		V_{SS}	V
	$V_{SS} - V_{DD}$ = 9.5V	V_{SS}−4.5		V_{SS}	V
Logic Low Level (V_{IL})				V_{DD}+1.5	V
K1–K4 Input Current Levels	(Through Keyboard)				
Input High Level (I_{IH})	$V_{IH} = V_{SS} - 3.2V$			−350	μA
D01, D04 Output Voltage Levels (Encoded Digit)					
Logic High Level (V_{OH})	R_L = 150 kΩ	V_{SS}−1.0		V_{SS}	V
Logic Low Level (V_{OL})	I_{OL} = 3 μA	V_{DD}		V_{DD}+0.5	V
Logic High Level Current (I_{OH})	$V_{SS} - V_{DD}$ = 7.9V				
	$V_{OH} = V_{DD} + 1.5V$			−260	μA
S_a–S_g and S_p Output Current Levels					
Logic High Level Current (I_{OH})	$V_{OH} = V_{DD} + 3V$				
Open Drain Outputs		−20	−10	−5	mA
Sync Output Voltage Levels	(With Load and Driver to V_{DD})				
	$V_{SS} - V_{DD}$ = 7.9V				
Logic High Level (V_{OH})	I_{OH} = −100 μA	V_{SS}−0.5		V_{SS}	V
Logic Low Level (V_{OL})	I_{OL} = 15 μA	V_{DD}		V_{DD}+3.7	V
F1 Output Voltage Levels					
Logic High Level (V_{OH})	I_{OH} = −30 μA	V_{SS}−1.5			V
Logic Low Level (V_{OL})	I_{OL} = 3 μA			V_{DD}+1.0	V
Osc. Output Current Levels	(Output with Load to V_{DD})				
Logic High Level Current (I_{OH})	$V_{OH} = V_{DD} + 1.5V$			−1.0	mA
Logic Low Level Current (I_{OL})	$V_{OL} = V_{DD} + 0.5V$	3.0			μA
Keyboard Key Resistance (R_{KEY}) (K1–K4)	LED Display Interface			200	Ω

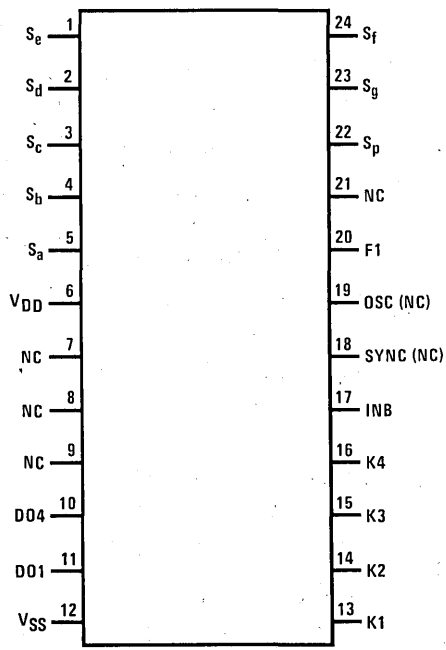
ac electrical characteristics

$0°C \leq T_A \leq +70°C$, $7.9V \leq V_{SS} - V_{DD} \leq 9.5V$ unless otherwise stated

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Osc. Output Frequency		130		450	kHz
Osc. Duty Cycle *(Figure 2)*		33	56	68	%
K1–K4, INB					
Input Timing					
t_{SK}		1.75			μs
t_{LK}		1.0			μs
F1 Output Timing	C_{LOAD} = 100 pF			4.4	μs
t_{pdf}					
Sync. Output Timing					
Interval (t_B, Bit Time)		8.8		30	μs
t_{pdsL}	C_L = 250 pF	0.1		1.65	μs
t_{pdsH}		0.1		1.25	μs
t_{HS}		0.1		0.8	μs
D01, D04 Output Timing	C_L = 100 pF (D01–D04) C_L = 250 pF (S0)				
t_{pd}		0.5		4.0	μs
S_a–S_g, S_p Output Timing (t_{pdSEG})				6.0	μs
Interdigit Blanking Time (T1)				7.5	μs

connection diagram

Dual-In-Line Package



TOP VIEW

Order Number MM57104N
See Package 22

functional description

REGISTER CONFIGURATION

The user has access to 5 registers designated X, Y, Z, T, and M. X is the display and entry register and the bottom of an "operational" stack that includes Y, Z and T. M is an independent user-addressable memory register that can be stored, recalled, added, multiplied, subtracted or divided with X. In the algebraic mode, Z and T are used as parenthesis registers.

All registers contain 8 mantissa digits with sign and 2 exponent digits with sign.

DISPLAY CONFIGURATION

The X-register is always displayed and shown as 8 digits of mantissa with sign or 5 digits of mantissa with sign and 2 digits of exponent with sign. Numbers are entered left justified with trailing zeros suppressed.

DISPLAY FORMAT

Floating point display output format is "F", "CS". If X is greater than 99999999. or less than 0.001, the display is in scientific notation.

By pressing "F", "EE" all results are displayed in scientific notation.

READY SIGNAL OPERATION

Output F1 of the MM57104 can be used as a "ready signal" to indicate calculator status. It can be useful in providing synchronization information during testing and if used with other logic.

When the calculator is in the "idle state" and ready to accept a key, F1 is high (near V_{SS}). It remains high until a key is depressed and accepted, then goes low. It goes low until the calculator is complete then goes high again to indicate that a new key may be entered.

KEYBOUNCE AND NOISE REJECTION

When a key is depressed, a time-out is started. A key is accepted as valid if it remains depressed for approximately 12 ms. The key must be released for at least 12 ms before a new key can be entered.

ERROR CONDITIONS AND INDICATION

In the event of an illegal operation, the calculator will display "Error" and X will be cleared. Any key depressed after an error will use X = 0 for the next operator. Table I summarizes results and operations that will give an error indication.

RANGE ACCURACY AND SPEED

All functions work over the full mathematically allowable range as defined by the error conditions.

All functions take less than 1 second and are accurate to 8 digits.

ALGEBRAIC OR RPN SELECTION

Leaving pin 17 (INB) open selects algebraic. Connect pin 17 to V_{SS} to select RPN.

TABLE I. Results and Operations Resulting in an Error Indication

Results $> 9.9999999 \times 10^{99}$
Results $< 1 \times 10^{-99}$
Division by 0
LOG, LN < 0
TAN, SIN, COS $> 9000°$
TAN 90°, 270°, etc.
SIN^{-1}, $COS^{-1} > 1$ or $\leq 10^{-50}$
$\sqrt{X} < 0$
More than two open parentheses without a close
More close parentheses than open

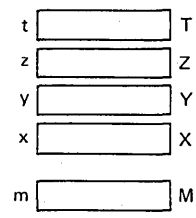


FIGURE 1. User Register Configuration

functional description (Continued)

KEY OPERATION

Clear Key, "C"

a) In RPN mode: Pushes down stack and clears T. Four "C" depressions will clear a completely full stack
b) After "F": Clears all registers including the memory
c) In algebraic mode after number key: Copy Y to X
d) In algebraic mode after function key: Clears all modes and all registers except M

Number Keys, "0" ~ "9", "·"

a) In RPN mode after any function key except "EN": Copies X to Y and clears X and enters number left justified to X
b) After any number key: Enters next digit $->$ X. All entries after eighth are ignored
c) After "EE": Enters number to exponent. Last 2 entries are used
d) After "EN": Clears X and enters number in X
e) In algebraic mode, after function key: Clears X and enters number

Change Sign Key, "CS"/"FLT"

a) After "EE": Change sign of exponent of X
b) After "F": Set floating point mode
c) After any other key: Changes sign of X mantissa

"F" "9" Reciprocal/"1/X"

Reciprocal of X to X

"F" "8" Power Key, "Y^X"

a) In RPN mode: Computes Y^X power, pushes down stack, clears T
b) In algebraic mode, not in chain mode: Copy X to Y, set Y^X chain mode
c) In algebraic mode, in chain mode: Perform the specified function of X and Y, putting the result to both X and Y, set Y^X chain mode

Enter Key, "EN", RPN Only

a) Pushes up stack, retains X
b) After F: (CF) resets F mode

Second Function Key, "F"

Sets F mode

Memory Recall/Memory Store, "MR/MS"

a) In RPN mode: Pushes up stack, recall memory to X
b) In algebraic mode: Recall X to M
c) After F: Copy X to M

Enter Exponent/Scientific Notation Key, "EE"/"SCI"

a) Sets enter exponent mode, displaying 00 in exponent position
b) After F: Set calculator to scientific notation

"X^2"/"$\sqrt{\ }$" Key, RPN Only

a) X squared to X
b) After F: Square root of X to X

Stack Rotate Key "ROLL"/"DEG" Key, RPN Only

a) Rolls stack down
b) After F: Convert radians to degrees

"F", "·" Exchange Key, "X↔Y"

Exchanges X and Y

"F", "5" Common Log Key

Common logarithm of X to X (Base 10)

"F" "6" 10^X Key

10^X to X

"F" "2" Natural Log Key

Natural logarithm of X to X (base e)

"F" "3" e^x Key

e^X to X

Trigonometic Keys, "F" "0", "F" "1", "F" "4" "SIN", COS, TAN"

a) Replaces the decimal angle in X with the indicated trigonometric function
b) After ARC: (SIN^{-1}, COS^{-1}, TAN^{-1}), replaces X with the decimal angle of the indicated inverse trigonometric function

The Four Function Keys, "+, −, X, ÷", In RPN Mode

a) Add key, "+": $Y + X \rightarrow X$
Subtract key, "−": $Y - X \rightarrow X$
Multiply key, "X": $Y \times X \rightarrow X$
Divide key, "÷": $Y/X \rightarrow X$
Then push down stack and clear T
$0 \rightarrow T \rightarrow Z \rightarrow Y$
b) After F: +: X + M to M
−: M − X to M
X: π to X
÷: Convert X from degrees to radians

functional description (Continued)

The Four Function Keys, "+", "−", "X", "÷", In Algebraic Mode

a) If not in chain mode: Copy X to Y, set the specified chain mode
b) After "+, −, X, ÷" key: Copy X to Y, set chain mode
c) In chain mode: Perform the specified function of X and Y putting the result to X and Y, set the specified chain mode

"F" "7" ARC Key

Set ARC mode

Equal Key "=", Algebraic Mode Only

a) In chain mode: Perform the specified function of X and Y putting the result to X' and save the last number displayed in Y, set the constant mode
b) In constant mode: Perform the specified function of X, Y putting the result in X
c) After F: (CF) reset F mode

Open Parenthesis, "[(", Algebraic Mode Only

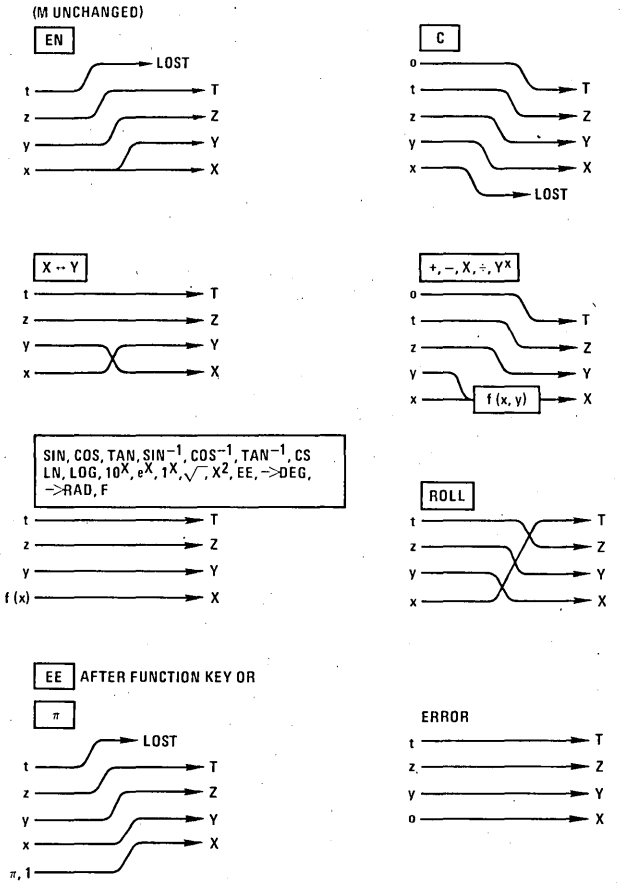
a) Copy X, T copy X to Z, copy P mode to P2 mode: Copy the calculator mode to P1 mode, reset calculator mode
b) After F: Square root of X to X

Close Parenthesis ")] ", Algebraic Mode Only

a) In chain mode: Perform the specified function of X, Y putting the result to X. Copy Z to Y, copy T to Z, clear T2. Copy P2 mode to P1 mode, copy P1 mode to the calculator mode, reset P2 mode
b) Not in chain mode: Z to Y, T to Z, clear T. P1 mode to calculator mode, P2 mode to P1 mode, reset P2 mode
c) After F; Convert radians to degrees

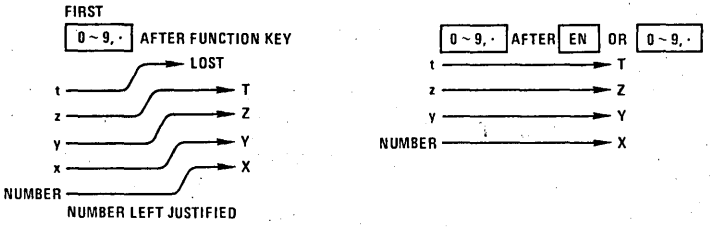
summary

Stack Operations in RPN Mode

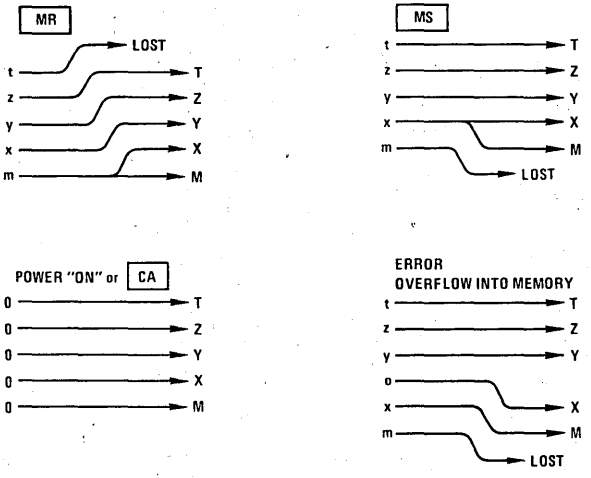


summary (Continued)

Stack Operations in RPN Mode (Continued)



Operations Using Memory(s)

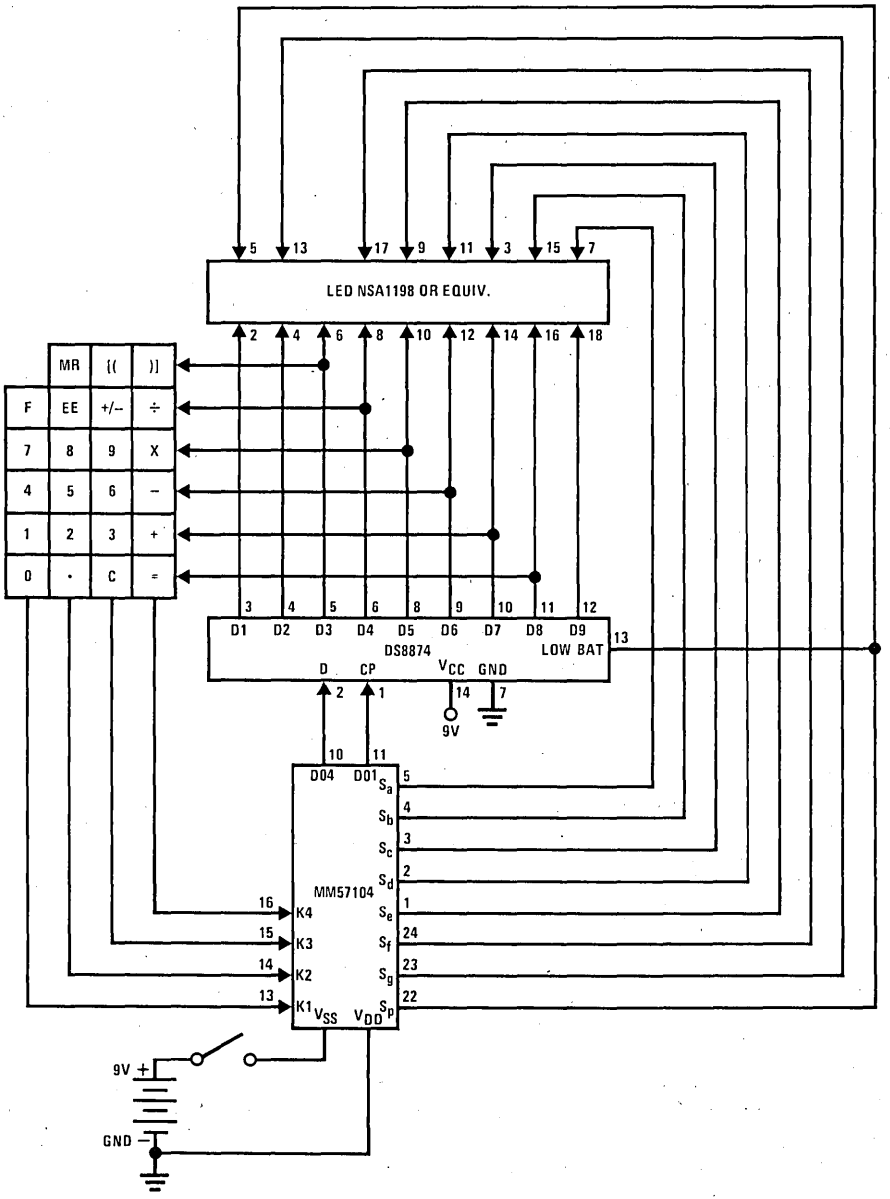


Example Showing Parenthesis Registers and Modes in Algebraic Mode

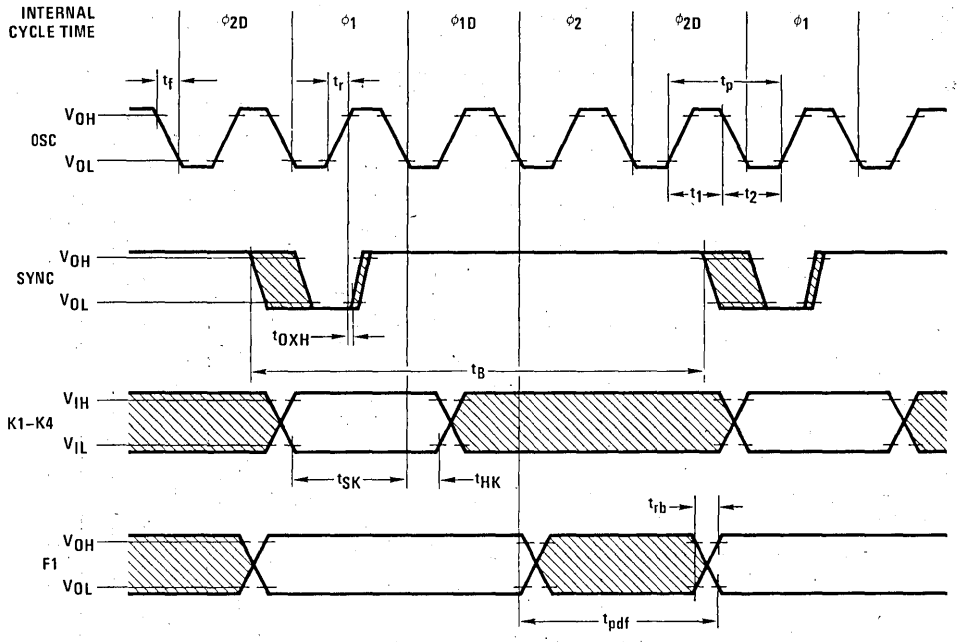
$6 \times (2^{(8-5)} + 2)$

	X	Y & MODE	P1 Z & MODE	P2 T & MODE
6	6			
X	6	6x		
(	6	6	6x	
2	2	6	6x	
FY^x	2	$2Y^x$	6x	
(	2	2	$2Y^x$	6x
8	8	2	$2Y^x$	6x
–	8	8–	$2Y^x$	6x
5	5	8–	$2Y^x$	6x
)	3	$2Y^x$	6x	
+	8	8+	6x	
2	2	8+	6x	
)	10	6x		
=	60	10x (constant)		

system interconnection diagram



switching time waveforms



Note. OSC Duty Cycle = $\frac{t_1}{t_1 + t_2} = \frac{t_1}{t_p}$

FIGURE 2(a). Input/Output Timing Diagram

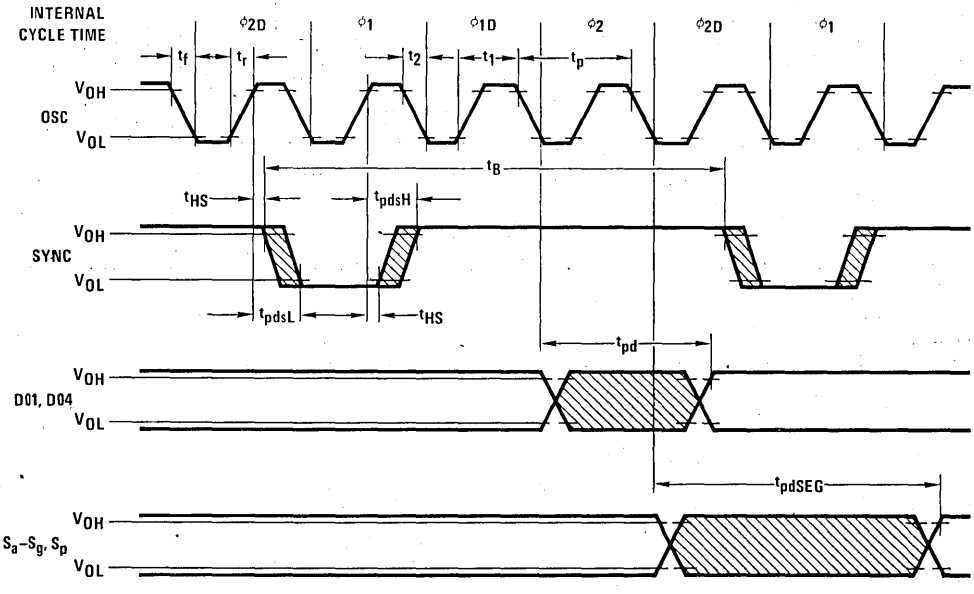


FIGURE 2(b). Input/Output Timing Diagram