



## MM57103 scientific calculator circuit

### general description

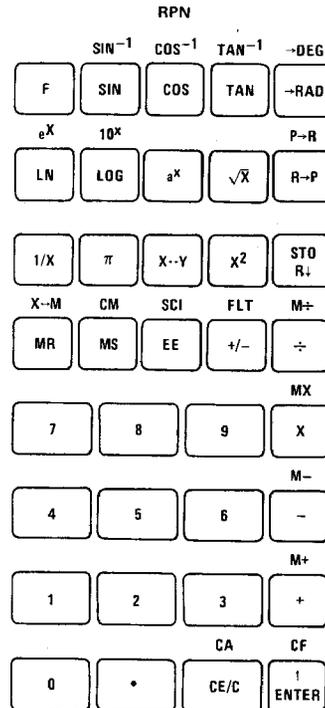
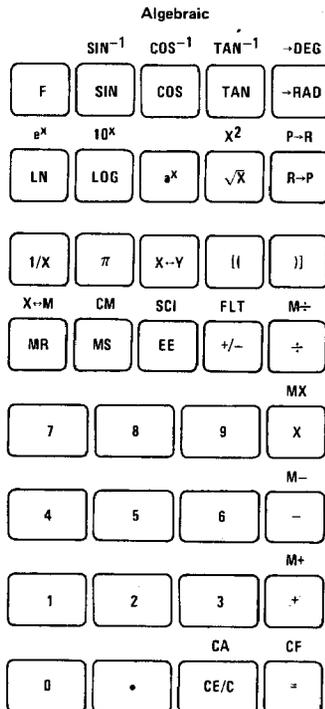
The MM57103 is a powerful one-chip scientific calculator device designed to provide the features and functions most desired by professionals. An 8-digit mantissa plus sign with a 2-digit exponent plus sign is featured. A 36-position keyboard (such as that illustrated below) was designed for convenience. Algebraic logic, combined with a fully accumulating 8-function memory in addition to two levels of parentheses are features most asked for in professional scientific calculators. With a simple pin connection, the MM57103 offers RPN logic with a 4-level stack in addition to the 8-function memory.

### features

- Enters and displays  $\pm 9.999999 \times 10^{99}$  to  $\pm 1. \times 10^{-99}$
- Left justified entry with trailing zero suppression

- Selectable Reverse Polish Notation (RPN) or Algebraic notation with 2 levels of parentheses
- Arithmetic functions: +, -, X,  $\div$ ,  $1/X$ ,  $\sqrt{X}$ ,  $X^2$
- 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)
- $\pi$ , change sign, clear, clear-all and exchange
- Auto power-on clear
- Degree/radian conversion
- Rectangular/polar conversion
- Two output modes: floating or scientific

### sample keyboards



**absolute maximum ratings**

Voltage at Any Pin Relative to V <sub>SS</sub> (All Other Pins Connected to V <sub>SS</sub> )	V <sub>SS</sub> +0.3V to V <sub>SS</sub> -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 ≤ T<sub>A</sub> ≤ +70°C, 7.9V ≤ V<sub>SS</sub> - V<sub>DD</sub> ≤ 9.5V unless otherwise stated

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Voltage (V <sub>SS</sub> - V <sub>DD</sub> )		7.9		9.5	V
Operating Supply Current (I <sub>DD</sub> )	V <sub>SS</sub> - V <sub>DD</sub> = 9.5V, T <sub>A</sub> = 25°C, (Excluding Outputs)		12	18	mA
Osc. Input Voltage Levels					
Logic High Level (V <sub>IH</sub> )	V <sub>SS</sub> - V <sub>DD</sub> = 7.9V	V <sub>SS</sub> -1.0			V
Logic Low Level (V <sub>IL</sub> )	V <sub>SS</sub> - V <sub>DD</sub> = 9.5V			V <sub>DD</sub> +1.5	V
Osc. Input Resistance To V <sub>SS</sub>			3		kΩ
K1-K4	(For Keyboard)				
Input Voltage Levels					
Logic High Level (V <sub>IH</sub> )	V <sub>SS</sub> - V <sub>DD</sub> = 7.9V	V <sub>SS</sub> -3.2		V <sub>SS</sub>	V
Logic Low Level (V <sub>IL</sub> )	V <sub>SS</sub> - V <sub>DD</sub> = 9.5V	V <sub>SS</sub> -4.5		V <sub>SS</sub>	V
K1-K4 Input Current Levels	(Through Keyboard)				
Input High Level (I <sub>IH</sub> )	V <sub>IH</sub> = V <sub>SS</sub> - 3.2V			-350	μA
D03 Input Voltage Levels					
Logic High Level (V <sub>IH</sub> )	7.9V ≤ V <sub>SS</sub> - V <sub>DD</sub> ≤ 9.5V	V <sub>SS</sub> -3.5			V
Logic Low Level (V <sub>IL</sub> )	V <sub>SS</sub> - V <sub>DD</sub> = 7.9V			V <sub>DD</sub> +2.5	V
	V <sub>SS</sub> - V <sub>DD</sub> = 9.5V			V <sub>DD</sub> +3.0	V
SI and Sync Input Voltage Levels					
Logic High Level (V <sub>IH</sub> )	V <sub>SS</sub> - V <sub>DD</sub> = 7.9V	V <sub>SS</sub> -1.2			V
Logic Low Level (V <sub>IL</sub> )	V <sub>SS</sub> - V <sub>DD</sub> = 7.9V			V <sub>SS</sub> -4.0	V
D01, D02, D04 Output Voltage Levels (Encoded Digit)					
Logic High Level (V <sub>OH</sub> )	R <sub>L</sub> = 150 kΩ	V <sub>SS</sub> -1.0		V <sub>SS</sub>	V
Logic Low Level (V <sub>OL</sub> )	I <sub>OL</sub> = 3 μA	V <sub>DD</sub>		V <sub>DD</sub> +0.5	V
Logic High Level Current (I <sub>OH</sub> )	V <sub>SS</sub> - V <sub>DD</sub> = 7.9V V <sub>OH</sub> = V <sub>DD</sub> + 1.5V			-260	μA
D03 Output Voltage Levels					
Logic High Level (V <sub>OH</sub> )	R <sub>L</sub> = 150 kΩ	V <sub>SS</sub> -1.0		V <sub>SS</sub>	V
Logic Low Level (V <sub>OL</sub> )	I <sub>OL</sub> = 3 μA	V <sub>DD</sub>		V <sub>DD</sub> +0.5	V
Logic High Level Current (I <sub>OH</sub> )	Battery Low "OFF", from DS8664 V <sub>OH</sub> = V <sub>DD</sub> + 3V V <sub>SS</sub> - V <sub>DD</sub> = 9.5V V <sub>OH</sub> = V <sub>DD</sub> + 2.5V V <sub>SS</sub> - V <sub>DD</sub> = 7.9V	-1.3		-0.3	mA
	Battery Low "ON", from DS8664 V <sub>OH</sub> = V <sub>SS</sub> - 3V V <sub>SS</sub> - V <sub>DD</sub> = 7.9V V <sub>OH</sub> = V <sub>SS</sub> - 3V V <sub>SS</sub> - V <sub>DD</sub> = 9.5V	-1.0		-0.4	mA
Logic High Level Current (I <sub>OH</sub> )				-0.4	mA
Sa-Sg and Sp Output Current Levels					
Logic High Level Current (I <sub>OH</sub> )	V <sub>OH</sub> = V <sub>DD</sub> + 3V	-20	-10	-5	mA

**dc electrical characteristics** (Continued)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Sync Output Voltage Levels	(With Load and Driver to $V_{DD}$ ) $V_{SS} - V_{DD} = 7.9V$				
Logic High Level ( $V_{OH}$ )	$I_{OH} = -100 \mu A$	$V_{SS}-0.5$		$V_{SS}$	V
Logic Low Level ( $V_{OL}$ )	$I_{OL} = 15 \mu A$	$V_{DD}$		$V_{DD}+3.7$	V
F1, F2, F3 Output Voltage Levels					
Logic High Level ( $V_{OH}$ )	$I_{OH} = -30 \mu A$	$V_{SS}-1.5$			V
Logic Low Level ( $V_{OL}$ )	$I_{OL} = 3 \mu A$			$V_{DD}+1.0$	V
BLK Output Voltage Levels					
Logic High Level ( $V_{OH}$ )	$I_{OH} = -0.5 mA$	$V_{SS}-1.5$			V
Logic Low Level ( $V_{OL}$ )	$I_{OL} = 5 \mu A$			$V_{DD}+1.0$	V
Keyboard Key Resistance ( $R_{KEY}$ ) (INB, K1-K4, F1-F3)	LED Display Interface			200	$\Omega$

**ac electrical characteristics**  $0^\circ C \leq T_A \leq +70^\circ C$ ,  $7.9V \leq V_{SS} - V_{DD} \leq 9.5V$  unless otherwise stated

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Osc. Input Frequency		320		400	kHz
Osc. Duty Cycle (Figure 2)		46	56	66	%
Osc. Input					
Rise Time ( $t_r$ )	$C_L = 25 pF$ , $R_L = 6 k\Omega$			350	ns
Fall Time ( $t_f$ )	$RC = 0.15 \mu s$			50	ns
K1-K4, D03					
Input Timing					
$t_{SK}$		1.75			$\mu s$
$t_{LK}$		1.0			$\mu s$
BLK Output Timing					
$t_{pdBLK}$	$C_{LOAD} = 50 pF$			4.4	$\mu s$
$t_{rb}$	$C_{LOAD} \leq 20 pF$	0.3			$\mu s$
F1, F2, F3 Output Timing	$C_{LOAD} = 100 pF$			4.4	$\mu s$
$t_{pdf}$					
Sync Output Timing					
Interval ( $t_B$ , Bit Time)	(For On-Chip Oscillator)	8.8		30	$\mu s$
$t_{pdsL}$	$C_L = 250 pF$	0.1		1.65	$\mu s$
$t_{pdsH}$		0.1		1.25	$\mu s$
$t_{HS}$		0.1		0.8	$\mu s$
D01, D02, D03, D04 Output					
Timing	$C_L = 100 pF$ (D01-D04) $C_L = 250 pF$ (S0)				
$t_{pd}$		0.5		4.0	$\mu s$
$S_a-S_g, S_p$ Output Timing ( $t_{pdSEG}$ )				6.0	$\mu s$
Interdigit Blanking Time (T1)				7.5	$\mu s$

## 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 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", "+-". If X is greater than 99999999. or less than .1, the display is in scientific notation.

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

### READY SIGNAL OPERATION

Output F1 of the MM57103 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<sub>SS</sub>). 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

Connect pin 5 (INB) to V<sub>DD</sub> to select algebraic mode. Connect to V<sub>SS</sub> to select RPN mode.

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 $> 9000^\circ$
TAN $90^\circ$ , $270^\circ$ , etc.
SIN <sup>-1</sup> , COS <sup>-1</sup> $> 1$ or $\leq 10^{-50}$
$\sqrt{X} < 0$
More than two open parentheses without a close
More close parentheses than open

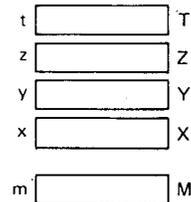


FIGURE 1. User Register Configuration

**functional description** (Continued)**KEY OPERATIONS****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 X, Y, Z and T

**Number Keys, "0" ~ "9", "."**

- a) In RPN mode after any function key except "EN": Clears X and enters number left justified to X
- b) After any number key: Enters next digit into 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"**

- a) After "EE": Change sign of exponent of X
- b) After any other key: Changes sign of X mantissa

**Coordinate Conversion Key, "R ↔ P"**

- a) Converts contents of X and Y in rectangular coordinates to polar coordinates:  
 $\sqrt{X^2 + Y^2}$  to Y  
 $\text{TAN}^{-1} Y/X$  to X
- b) After "F": (P → R): Converts contents of X and Y in polar coordinates to rectangular coordinates:  
 $Y \text{ SIN } X \rightarrow Y \quad (\Omega \text{ SIN } 0)$   
 $Y \text{ COS } X \rightarrow X \quad (\Omega \text{ COS } 0)$

**Square Root/Square Key, " $\sqrt{X}/X^2$ "**

- a) Square root of X to X
- b) After "F":  $(X^2)$  X-squared to X

**Reciprocal/"1/x"**

Reciprocal of X to X

**Power Key "YX"**

- 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"**

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

**Second Function Key, "F"**

Sets F mode

**Memory Store/Clear "MS"/"MC"**

- a) Copy X to memory
- b) After F: (CM) clear memory

**Memory Recall/Exchange Memory "MR/X-M"**

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

**Enter Exponent Key, "EE"**

Sets enter exponent mode, displaying 00 in exponent position.

**Stack Rotate Key "ROLL", RPN Only**

Rolls stack down

**Exchange Key, "X ↔ Y"**

Exchanges X and Y

**Common Log Key, "LOG/10<sup>X</sup>"**

- a) Common logarithm of X to X (base 10)
- b) After "F":  $(10^X)$   $10^X$  to X

**Natural Log Key, "LN/e<sup>X</sup>"**

- a) Natural logarithm of X to X (base e)
- b) After "F":  $(e^X)$   $e^X$  to X

**Trigonometric Keys, "SIN, COS, TAN"**

- a) Replaces the decimal angle in X with the indicated trigonometric function
- b) After F:  $(\text{SIN}^{-1}, \text{COS}^{-1}, \text{TAN}^{-1})$  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:  $M \times X$  to M
  - ÷:  $M/X$  to M

## functional description (Continued)

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

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

### $\pi$ Key, " $\pi$ "

- In RPN mode: Pushes up stack enter  $\pi$  to X (3.1415927)
- In algebraic mode: Enter  $\pi$  to X

### Degree to Radian Key, "D $\rightarrow$ R"

- Converts X in degrees to radians  $X = X_0/180 \times \pi$
- Converts X in radians to degrees  $X = X_0/\pi \times 180$

### Equal Key, "="

- 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

- In constant mode: Perform the specified function of X, Y putting the result in X
- After F: (CF) reset F mode

### Open Parenthesis, "{("

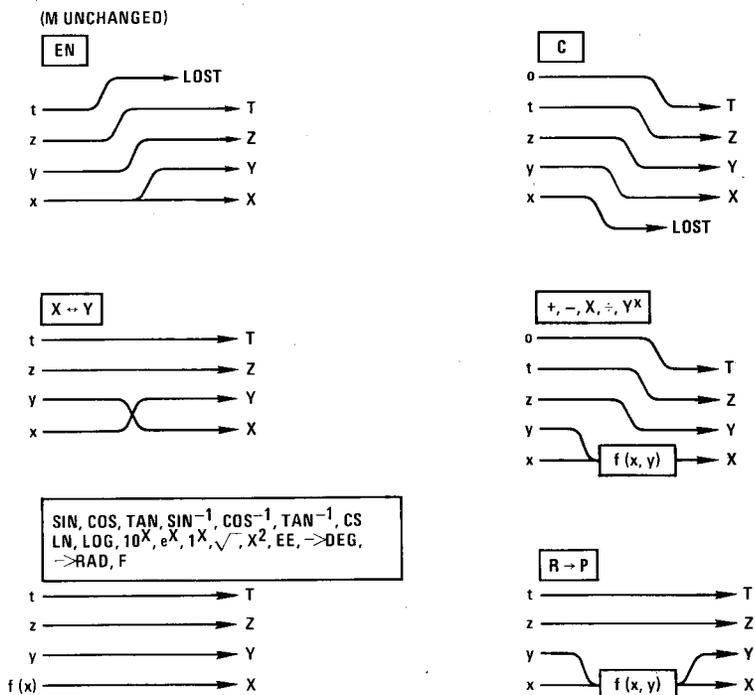
Copy Z to T, copy X to Z; copy P1 mode to P2 mode; copy the calculator mode to P1 mode, reset calculator mode

### Close Parenthesis ")", Algebraic Mode

- 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
- 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

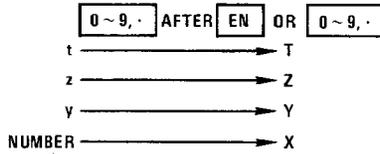
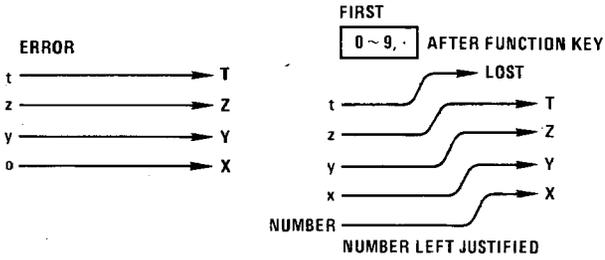
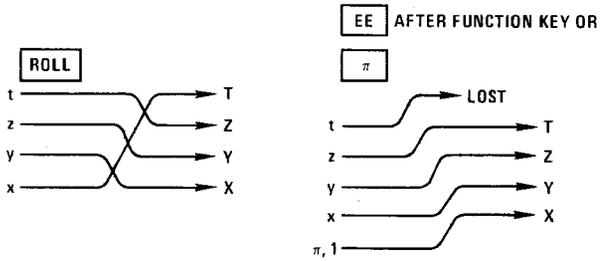
## summary

### Stack Operations in RPN Mode

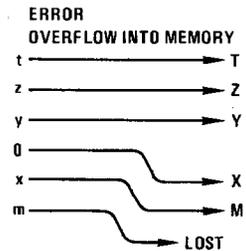
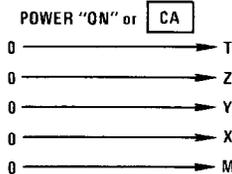
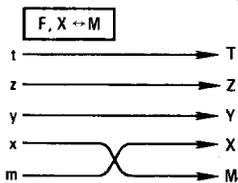
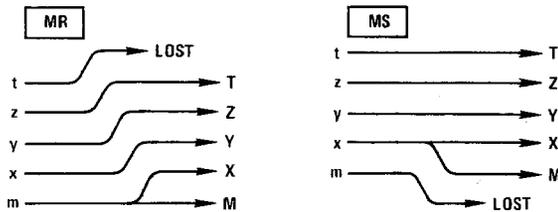


summary (Continued)

Stack Operations in RPN Mode (Continued)



Operations Using Memory(s)

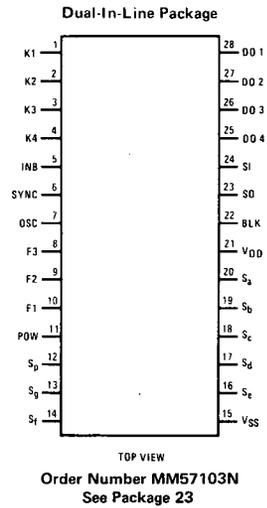


Example Showing Parentheses Registers and Modes in Algebraic Mode

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

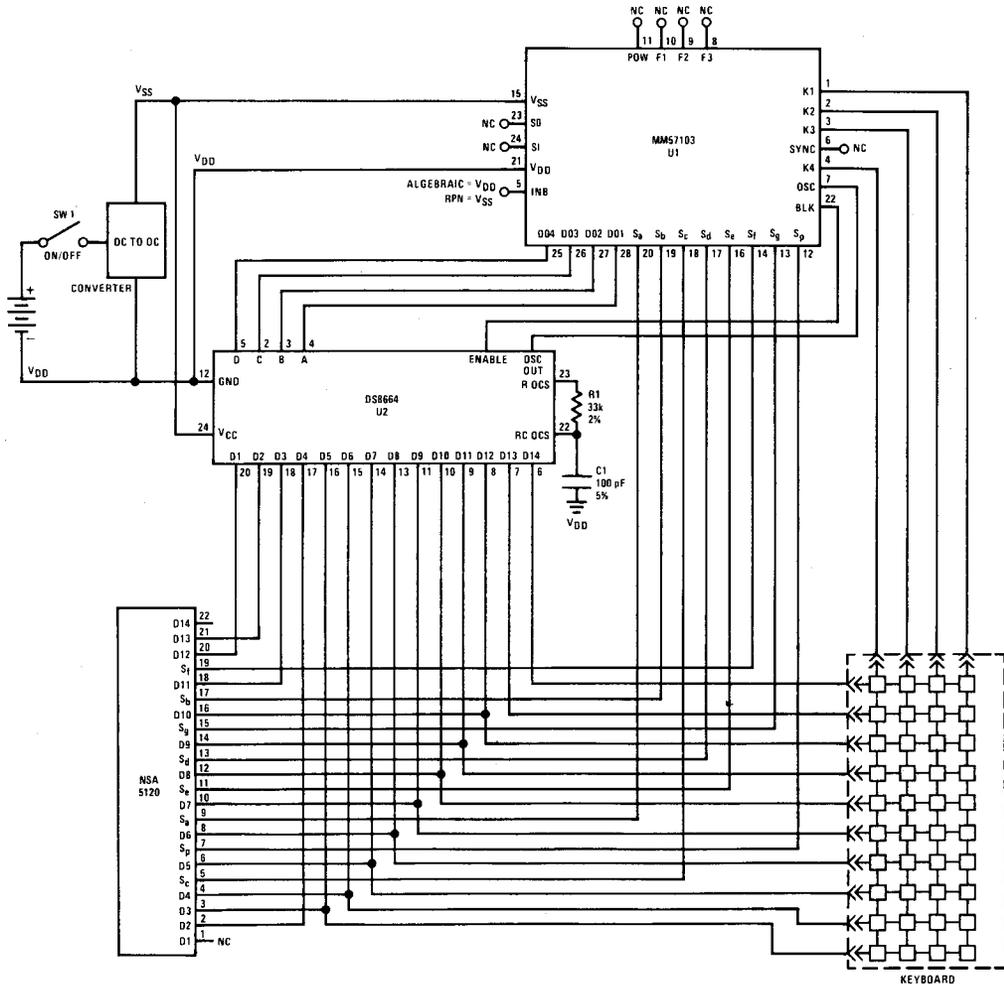
	X	Y & MODE	P1 Z & MODE	P2 T & MODE
	6			
X	6	6x		
(	6	6	6x	
2	2	6	6x	
FY <sup>X</sup>	2	2Y <sup>X</sup>	6x	
(	2	2	2Y <sup>X</sup>	6x
8	8	2	2Y <sup>X</sup>	6x
-	8	8+	2Y <sup>X</sup>	6x
5	5	8-	2Y <sup>X</sup>	6x
)	3	2Y <sup>X</sup>	6x	
+	8	8+	6x	
Z	Z	8+	6x	
)	10	6x		
=	60	10x (constant)		

connection diagram



typical application

Typical Scientific Calculator Schematic



switching time waveforms

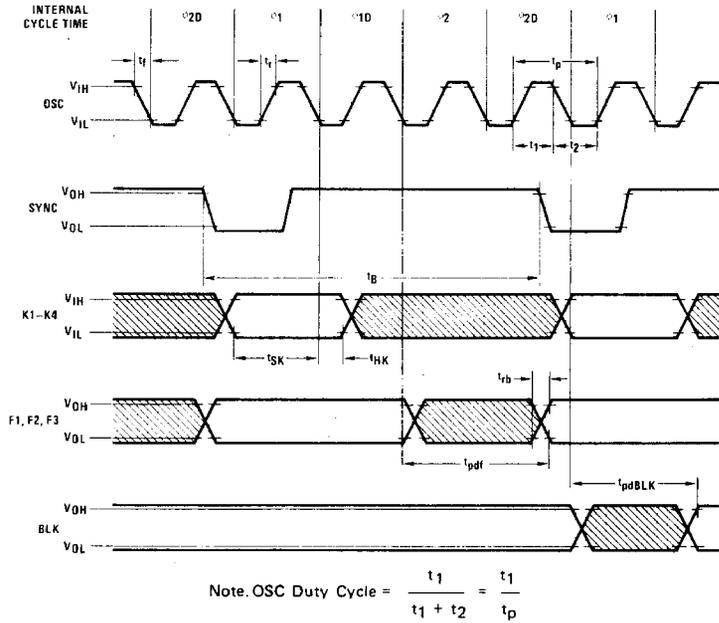


FIGURE 2(a). Input/Output Timing Diagram

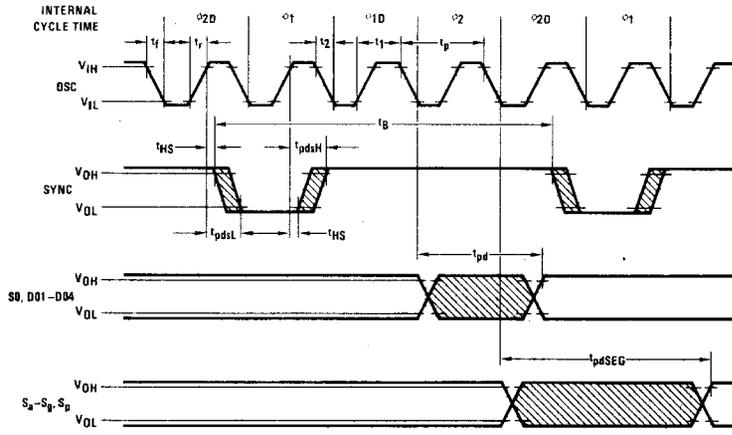


FIGURE 2(b). Input/Output Timing Diagram

keyboard matrix connection table

SWITCH INPUTS	DIGIT TIMING STATE									
	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5
K1		=	+	C	•	0	3	2	1	
K2		X	-	9	8	7	6	5	4	
K3	M+	[ (	÷	) ]	%	Σ+	CS	EE	MS	MR
K4	F	D.MS	R → P	TAN	COS	SIN	√	1/X	LOG	LN