



MM5760 slide rule calculator general description

The single-chip MM5760 Slide Rule Calculator was developed using a metal-gate, P-channel enhancement and depletion mode MOS/LSI technology with the primary objective of low end-product cost. A complete calculator as shown in *Figure 1* requires only the MM5760, a keyboard, DM8864 digit driver, NSA298 LED display and a 9V battery with appropriate hardware.

Keyboard decoding and key debounce circuitry, all clock and timing generation and 7-segment output display encoding are included on-chip and require no external components. Segments can usually be driven directly from the MM5760, as it typically sources about 8.5 mA of peak current. (Note: the typical duty cycle of each digit is 0.104; average LED segment current is therefore approximately 0.89 mA.) The left-most digit is used for the negative sign or the decimal point of a number less than unity.

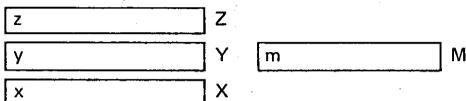
An internal power-on clear circuit clears all registers, including the memory, when V_{DD} and V_{SS} are initially applied to the chip.

Trailing zero suppression allows convenient reading of the left justified display, and conserves power. The DM8864 digit driver is capable of sensing a low battery voltage and providing a signal during Digit 9 time that can be used to turn on one of the segments as an indicator. Typical current drain of a complete calculator displaying five "5's" is 30 mA. Automatic display cutoff is included. If no key closure occurs for approximately 35 seconds, all numbers are blanked and all decimal points displayed.

The Ready output signal is used to indicate calculator status. It is useful in providing synchronization information during testing and when the MM5760 is used with other logic or integrated circuits; e.g., with the MM5765 Programmer (*Figure 3*).

Thirty-two keys are arranged in a four-by-nine matrix (*Figure 1*). In addition to seven arithmetic functions plus logarithmic, trigonometric and accumulating memory functions, the calculator is capable of calculating Y^X , adding the square of X to memory, automatically entering π and providing degrees/radian conversions.

The user has access to four registers designated X, Y, Z and M. X is the display and entry register, and is the bottom of a "push-up" stack that also includes registers Y and Z:



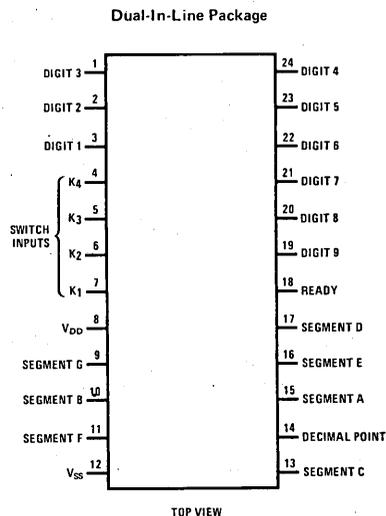
Note: Lower case letters designate the data in the register identified by a capital letter.

Calculators

features

- Full 8-digit entry and display capacity
- Complete electronic slide rule capability
 - Arithmetic functions: +, -, x, ÷, \sqrt{x} , $1/x$, x^2
 - Logarithmic functions: $\ln x$, $\log x$, e^x
 - Trigonometric functions: $\sin x$, $\cos x$, $\tan^{-1} x$, $\arcsin x$, $\arccos x$, $\arctan x$
 - Other functions: Y^X , π , change sign, exchange, $x^2 + \text{memory} \rightarrow \text{memory}$, radians to degrees, degrees to radians
- Three-register operational stack
- Independent accumulating storage register with store, recall, memory plus and memory minus functions
- Floating point input and output
- Direct 9V battery compatibility; low power
- Power-on clear
- No external components required other than display digit driver, keyboard and LED display for complete calculator
- Error indication for over range, overflow and invalid operations
- Left justified entry and results with trailing zero suppression
- Automatic display cutoff
- Reverse polish notation

connection diagram



Order Number MM5760N
See Package 22

absolute maximum ratings

Voltage at Any Pin Relative to V_{SS} $V_{SS} + 0.3V$ to $V_{SS} - 12V$
 (All other pins connected to V_{SS})
 Ambient Operating Temperature $0^{\circ}C$ to $+70^{\circ}C$
 Ambient Storage Temperature $-55^{\circ}C$ to $+150^{\circ}C$
 Lead Temperature (Soldering, 10 seconds) $300^{\circ}C$

operating voltage range

$6.5V \leq V_{SS} - V_{DD} \leq 9.5V$
 V_{SS} is always defined as the most positive supply voltage.

dc electrical characteristics

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Current (I_{DD})	$V_{DD} = V_{SS} - 9.5V$, $T_A = 25^{\circ}C$			16.0	mA
Keyboard Scan Input Levels (K1, K2, K3 and K4)					
Logical High Level	$V_{SS} - 6.5V \leq V_{DD} \leq V_{SS} - 9.5V$	$V_{SS} - 2.5$		$V_{SS} - 5.0$	V
Logical Low Level	$V_{DD} = V_{SS} - 6.5V$ $V_{DD} = V_{SS} - 9.5V$			$V_{SS} - 6.0$	V
Digit Output Levels					
Logical High Level (V_{OH})	$R_{LOAD} = 3.2 k\Omega$ to V_{DD} $V_{SS} - 6.5V \leq V_{DD} \leq V_{SS} - 9.5V$	$V_{SS} - 1.5$			V
Logical Low Level (V_{OL})	$V_{DD} = V_{SS} - 6.5V$ $V_{DD} = V_{SS} - 9.5V$			$V_{SS} - 6.0$ $V_{SS} - 7.0$	V V
Segment Output Current (Sa through Sg and Decimal Point)	$T_A = 25^{\circ}C$ $V_{OUT} = V_{SS} - 3.6V$, $V_{DD} = V_{SS} - 6.5V$ $V_{OUT} = V_{SS} - 5V$, $V_{DD} = V_{SS} - 8V$ $V_{OUT} = V_{SS} - 6.5V$, $V_{DD} = V_{SS} - 9.5V$	-5.0	-8.5 -10.0	-15.0	mA mA mA
Ready Output Levels					
Logical High Level (V_{OH})	$I_{OUT} = -0.4 mA$	$V_{SS} - 1.0$			V
Logical Low Level (V_{OL})	$I_{OUT} = 10\mu A$			$V_{DD} + 1.0$	V

ac electrical characteristics

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Word Time (Figure 2)		0.32	0.65	1.3	ms
Digit Time (Figure 2)		36	70	145	μs
Segment Blanking Time (Figure 2)		2	4.5	9	μs
Digit Output Transition Times (t_{RISE} and t_{FALL})	$C_{LOAD} = 100 pF$, $R_{LOAD} = 9.6 k\Omega$		2		μs
Keyboard Inputs High to Low Transition Time After Key Release	$C_{LOAD} = 100 pF$		4		μs
Ready Output Propagation Time (Figure 3)					
Low to High Level (t_{PDH})	$C_{LOAD} = 100 pF$	10		50	μs
High to Low Level (t_{PDL})	$C_{LOAD} = 100 pF$			1	ms
Key Input Time-out					
Key Entry		2.8	6.0	11.7	ms
Key Release		5.1	10.4	20.5	ms
Display Cutoff Time (The time after the last valid key closure that all numbers will be blanked and all decimal points displayed.)		10	22	44	second

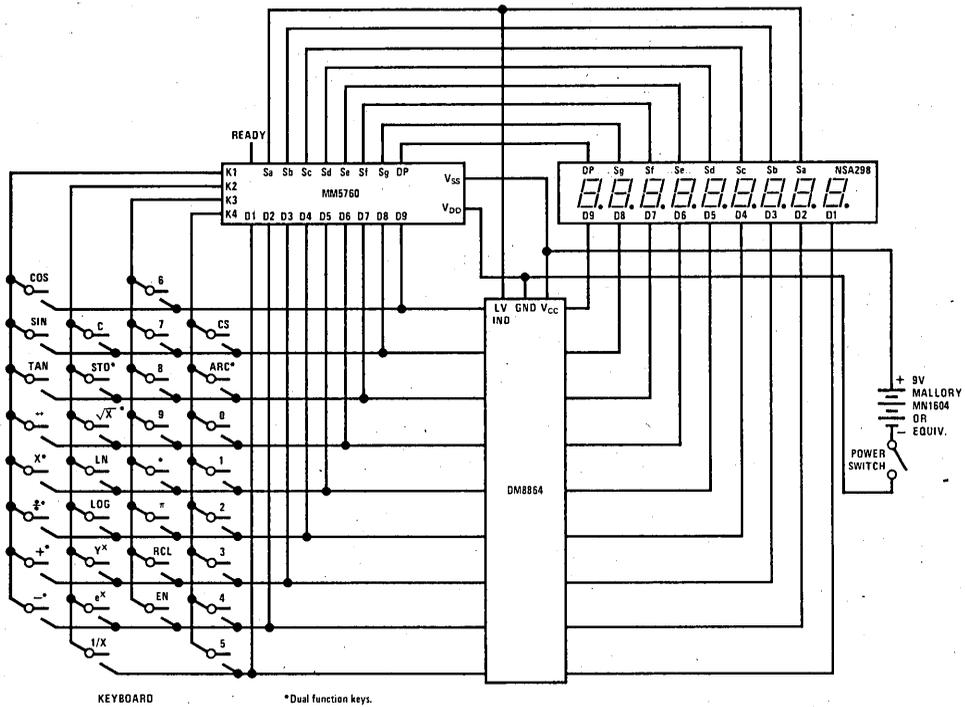


FIGURE 1. Complete Calculator Schematic

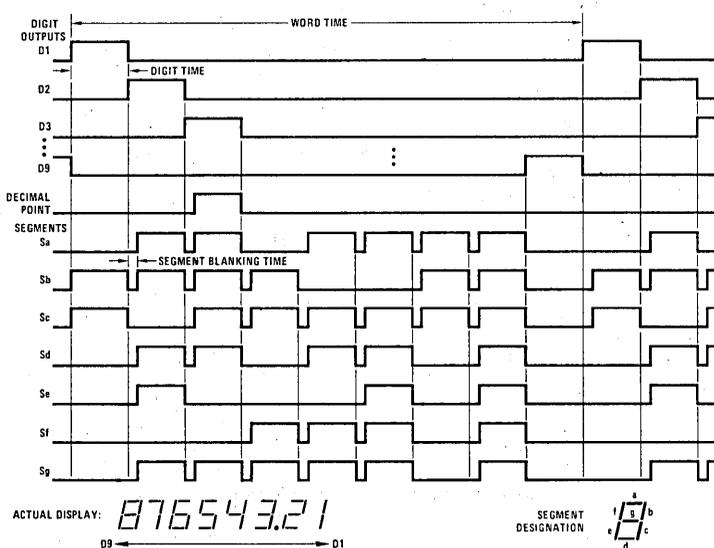


FIGURE 2. Display Timing Diagram

The contents of the accumulating storage register M are replaced with the contents of the X register by using the "STO" key. Preceding "+" or "-" with the "ARC" key sums X into M, or subtracts X from M. "ARC" followed by "STO" squares X and sums it into the memory without changing the value of X. The memory recall key, "RCL," copies M into X without disturbing the value of M. Storage register M is cleared automatically at

power-on or by storing a zero. All registers contain eight digits and sign information.

Inputs are entered and outputs displayed in floating point. The output results are truncated. Data entry always precedes the operation keys that operate on them; this is referred to as Reverse Polish notation. (See examples.)

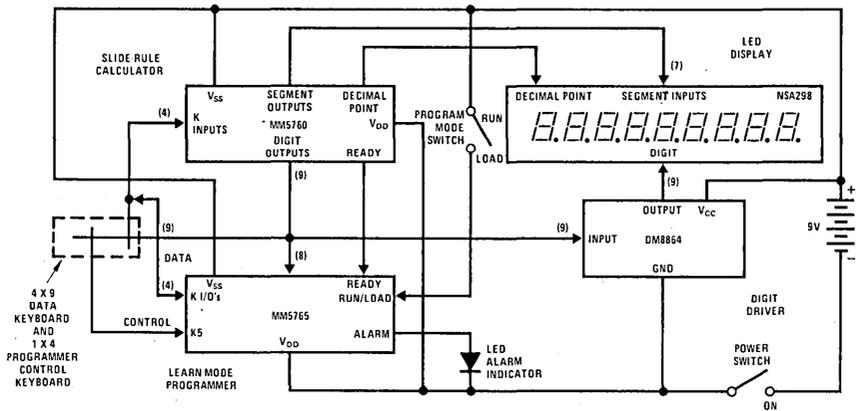


FIGURE 3. Low Cost Hand Held Programmable Electronic Slide Rule Using the MM5760 Calculator and MM5765 Programmer

KEY SEQUENCE EXAMPLES

KEY	DISPLAY	COMMENTS
	0.	Power-On Clear
1	1	
0	10	
0	100	
LOG	2.	
EN	2.	Copy X into Y
10	10	
C	2.	Clear X, stack pushes down
C	0.	Stack cleared
10	10	
EN	10.	
2	2	
Y ^x	99.99993	6 digit accuracy. Typical calculation time = 1.7 seconds
50	50	
+	149.99993	
4	4	
√X	2.	Typical calculation time = 90 ms
EN	2.	
7	7	
-	-5.	
2	2	
X	-10.	
÷	-14.999993	
9	9	
STO	9.	"STO" terminates data entry
3	3	
ARC	3	
SIN	.0.0.0.0.0.0.0	Error indication (X > 1) No clear needed
.	.	
1	.1	
LN	-2.302585	Typical calculation time = 260 ms
RCL	9.	
1/X	.11111111	
9	9	
↔	.11111111	Exchange X and Y
Y ^x	1.276517	1 ⁹ √9 = 9 ^{1/9}
.8	.8	
ARC	.8	
ARC	.8	Second "ARC" ignored
SIN	53.1301	SIN ⁻¹ in degrees
SIN	.8	SIN of 53.1301°

KEY SEQUENCE EXAMPLES (Con't)

KEY	DISPLAY	COMMENTS
ARC	.8	
COS	3.68699	COS^{-1} in degrees
COS	.8	COS of 36.8699
ARC	.8	
TAN	38.65981	TAN^{-1} in degrees
TAN	.8	TAN of 38.65981
LOG	-0.9691	
LN	.000000000	
e^x	1.	e^x for $X = 0$
π	3.1415926	
C	1.	
C	1.276517	
C	0.	
LN	.000000000	
1	1	
CS	-1	
STO	-1.	
ARC	-1.	
COS	180	
ARC	180	
TAN	89.68169	
RCL	-1.	
e^x	3.678796	
RCL	-1.	
ARC	-1.	
SIN	-90.	
ARC	-90.	
\div	-1.5707963	90° in radians
ARC	-1.5707963	
+	-1.5707963	Accumulate X in M
RCL	-2.5707963	Recall M

EXAMPLE DEMONSTRATING STACK OPERATIONS

$$\text{Evaluate: } \frac{\text{LOG} \left(\frac{14 + 26}{6 - \sqrt{4}} \right)}{\text{SIN} (25 + 5)}$$

KEY	STACK REGISTERS			COMMENTS
	X	Y	Z	
14	14	?	?	Y and Z are unknown
EN	14.	14	?	
26	26	14	?	14 + 26 = 40
+	40.	?	0	
6	6	40	?	40
EN	6.	6	40	
4	4	6	40	40
\sqrt{x}	2.	6	40	
-	4.	40	0	$\sqrt{4} = 2$
\div	10.	0	0	$6 - \sqrt{4} = 4$
LOG	1.	0	0	$(14 + 26)/6 - \sqrt{4} = 10$
25	25	1	0	$\text{LOG} [(14 + 26)/(6 - \sqrt{4})] = 1$
EN	25.	25	1	
5	5	25	1	
+	30.	1	0	
SIN	.5	1	0	$\text{SIN} (25 + 5) = 0.5$
\div	2.	0	0	$\text{LOG} [(14 - 26)/(6 - \sqrt{4})] = 2$
C	0.	0	0	$\text{SIN}(25 + 5)$

KEYBOARD BOUNCE AND NOISE REJECTION

The MM5760 is designed to interface with most low cost keyboards, which are often the least desirable from a false or multiple entry standpoint.

A key closure is sensed by the calculator chip when one of the key inputs, K1, K2, K3 or K4 is forced more positive than the Logical High Level specified in the Electrical Specifications. An internal counter is started as a result of the closure. The key operation begins after nine word times if the key input is still at a Logical High Level. As long as the key is held down (and the key input remains high) no further entry is allowed. When the key input changes to a Logical Low Level, the internal counter starts a sixteen word time-out for key release. During both entry and release time-outs the key inputs are sampled approximately every other word time for valid levels. If they are found invalid, the counter is reset and the calculator assumes the last valid key input state.

One of the popular types of low-cost keyboards available, the elastomeric conductor type, has a key pressure versus contact resistance characteristic that can generate continuous noise during "teasing" or low pressure key depressions. The MM5760 recognizes a series contact resistance up to 50 k Ω as a valid key closure, assuring a reliable interface for that type of keyboard.

AUTOMATIC DISPLAY CUTOFF

If no key is depressed for approximately 35 seconds, an internal automatic display cutoff circuit will blank all segments and display nine decimal points. Any key depression will restore the display; to restore the display without modifying the status of the calculator, use two change sign, "CS," depressions.

READY SIGNAL OPERATION

The Ready signal indicates calculator status. When the calculator is in an "idle" state the output is at a Logical High Level (near V_{SS}). When a key is closed, the internal key entry timer is started. Ready remains high until the time-out is completed and the key entry is accepted as valid, then goes low as indicated in *Figures 4 and 5*. It remains at a Logical Low Level until the function initiated by the key is completed and the key is released. The low to high transition indicates the calculator has returned to an idle state and a new key can be entered.

ERROR INDICATION

In the event of an operating error, the MM5760 will display all zeros and all decimal points. In addition to normal calculator overflow situations which occur as a result of adding, subtracting, multiplying or dividing and including division by zero, the error indication is displayed for the conditions of Table I.

The Z-register is automatically cleared and the Y- and M-registers are saved. An error condition is cleared by depressing any key except "1/X," " \div ," "LOG X" or "LN X." Operation on the X register with an error displayed will be performed as if X contained a zero.

KEY OPERATIONS

(Note: Register X is always displayed.)

Clear Key, "C"

After any key except "ARC," it clears X, pushes Y down to X, Z to Y and places a zero in Z. Subsequent depressions perform the same function; thus, three "C" depressions after a number entry will clear a completely

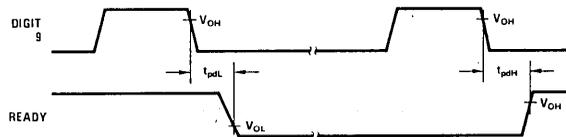


FIGURE 4. Ready Timing

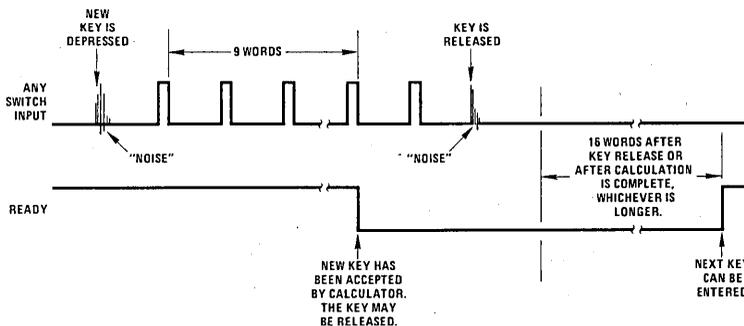


FIGURE 5. Functional Description of Ready Signal and Key Entry

TABLE I. Conditions for Error Indication

FUNCTION	CONDITIONS (REGISTER X \equiv X)
+ , - , x , \div	Result > 99999999.
\div or 1/X	$ X \leq 0.00000001$
\sqrt{X}	$X < 0$
Y^X	$Y \leq 0$ $\&n 99999999 < X \&n Y < -28$
log X or ln X	$X \leq 0.00000001$
e^X	$\&n 99999999 < X < -28$
Sin X or Cos X	$X \geq 7$ radians or $\sim 401^\circ$
ARC Sin X or ARC Cos X	$X > 1$
Tan X	$X = \pm 90^\circ$, or $X \geq 7$ radians

Note: $\&n 99999999 = 18.420680$

full stack. This is also the method used to gain access to the Z register. Memory register M is not affected by "C." Pressing "C" after "ARC" resets the ARC function without affecting any of the data registers.

Number Entries

First entry after "EN" clears X and enters the number into Digit 8 (the second digit from the left of the display) of X. Second through eighth entry (excluding a decimal point) enters the number one digit to the right of the last number entered. The ninth, and subsequent entries, are ignored. The first number key after any key other than "EN" loses Z, pushes Y up to Z, X to Y, clears X and enters the number in Digit 8 of X.

Decimal Point, "."

After an ENTER key, it clears X and displays a decimal point in the left-most digit position. Following a number entry, it places a decimal point to the right of the last number entered. Subsequent depressions without an interceding number entry are ignored; subsequent depressions after interceding number entries will replace the previous point with one to the right of the last entered number.

Change Sign Key, "CS"

Changes the sign of X.

Enter Key, "EN"

Register Z is lost; Y is pushed up to Z and X is copied into Y.

Addition Key, "+"

X is added to Y and the result is placed in X. Z is transferred to Y and cleared. Following an "ARC" key, "+" adds the contents of X to M without changing X, Y or Z.

Subtraction Key, "-"

X is subtracted from Y and the result is placed in X. Z is copied into Y, then cleared. Following an "ARC" key, "-" subtracts the contents of X from M without changing X, Y or Z.

Multiplication Key, "X"

X is multiplied by Y and the result is placed in X. Z is transferred to Y and cleared. Following an "ARC" key, "X" converts the value of X from radians to degrees without changing M, Y or Z.

Division Key, " \div "

X is divided into Y and the result is placed in X. Z is transferred to Y and cleared. Following an "ARC" key, " \div " converts the value of X from degrees to radians without changing M, Y or Z.

Pi Key, " π "

Register Z is lost; Y is pushed up to Z and X to Y. The constant 3.1415926 is placed in X.

Exchange Key, " \leftrightarrow "

Registers X and Y are exchanged. Z and M are not affected.

Inverse Trigonometric and Multifunction Key, "ARC"

When used as a prefix to one of the trigonometric keys it conditions the calculator to determine the inverse function of the value in X. For example "ARC" followed by "SIN" computes the angle that has a sine equal to the value of X, replacing X with that angle in degrees. See key descriptions of "+", "-", "X", " \div ", " \sqrt{X} ", "STO" and "C" for secondary functions assigned to those keys by preceding them with "ARC." "ARC" followed by any key other than one of the above or one of the trig functions will be ignored.

Reciprocal Key, "1/X"

A non-zero value of X is replaced by its reciprocal. Registers M, Y and Z are not altered.

Square Root Key, " \sqrt{X} "

A positive value of X is replaced by its square root. Registers Y and Z are not altered. Following an "ARC" key, " \sqrt{X} " replaces the value of X with its square. Registers M, Y and Z are not affected.

Logarithmic Keys, "LN" and "LOG"

These keys replace the value of X by its natural or common logarithm, respectively; register Z is lost. M is not altered.

Exponential Key, "e^X"

Determines the value of 2.7182818 raised to the power contained in register X, and places that value in X. The contents of Z are lost and Z is cleared. M is not altered.

Power Key, "Y^X"

Determines the value of Y raised to the power of X and

replaces X with the result. The contents of Z are lost, Y retains the exponent and Z is cleared. M is not affected.

Memory Keys, "STO" and "RCL"

The memory store key, "STO" copies the value of X (including sign) into storage register M without altering the stack. "STO" following "ARC" squares the value of X and accumulates the result into M. Registers X, Y and Z are not affected. The recall key, "RCL," transfers Y to Z and X to Y, then copies M into X. Storage register M is not changed and Z is lost. Both "STO" and "RCL" terminate the entry mode.

MEMORY OPERATIONS RESULTING IN ERROR CONDITIONS

Any operation in which the storage register M is involved that results in an error condition, will not affect the previous contents of M. For example, if by accumulating X into M ("ARC," "+") the contents of M will become greater than 999999999, an error indication will occur and the original contents of M are protected. As a result of the overflow, registers X and Z will be lost as shown in Table II.

TABLE II. Summary of Stack Operations

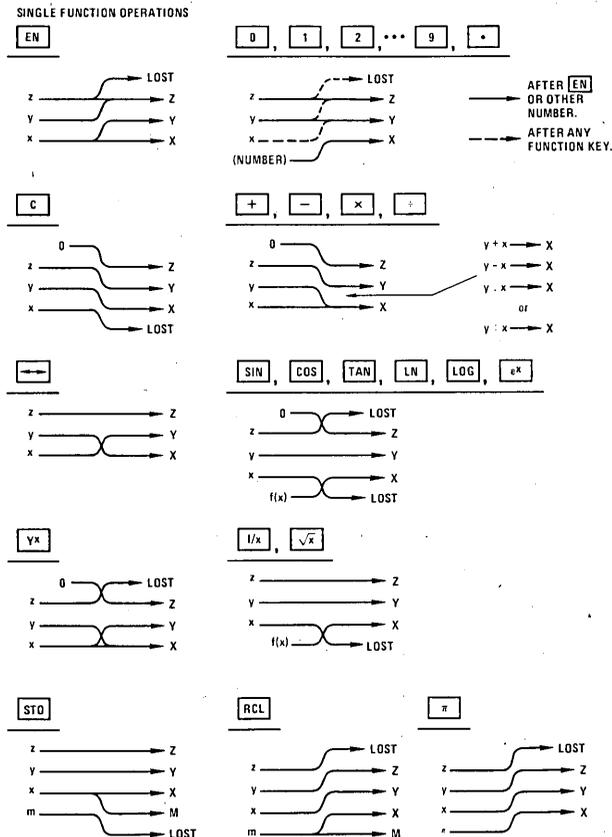
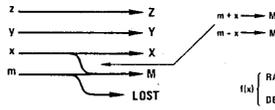


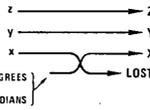
TABLE II. Summary of Stack Operations (Cont'd)

SECOND FUNCTION SEQUENCES

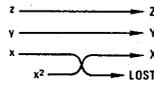
ARC FOLLOWED BY +, -



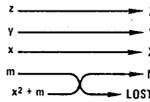
ARC FOLLOWED BY x, ÷



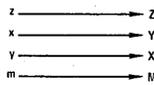
ARC FOLLOWED BY √x



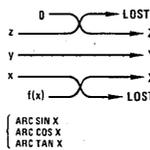
ARC FOLLOWED BY STO



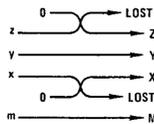
ARC FOLLOWED BY C



ARC FOLLOWED BY SIN, COS OR TAN



ERROR INDICATION



RANGE AND ACCURACY OF FUNCTIONS

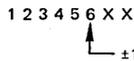
The smallest magnitude that can be displayed is ±0.00000001 and the total range is from -99999999 to +99999999. The arithmetic functions (+, -, x, ÷, 1/X,

√x, x²) have eight digit accuracy. All results are truncated. Table III summarizes range and accuracy of the other functions. Arithmetic calculations will be completed in less than 0.5 second; all others except Y^x in less than 2.5 seconds and Y^x in less than 5 seconds.

TABLE III. Digit Accuracy for Various Functions

FUNCTION	RANGE	APPROXIMATE ACCURACY (Note 1)
SIN, COS, TAN	~ -90° to ~ 90° ~ -360° to ~ 360°	7 Digits 6 Digits
ARC SIN and ARC COS	~ -1 to ~ +1	6 Digits
ARC TAN	-99999999 to 99999999	6 Digits
LOG	X ≥ 0	6 Digits
e ^x	-28 ≤ X ≤ ln 99999999	6 Digits
LN	X ≥ 0	6 Digits
√x	X ≥ 0	8 Digits
Y ^x	Y > 0 X ln Y ≤ ln 99999999	5 Digits

Note 1: Six digit accuracy, as an example, would be:



n digit accuracy has the nth digit from the MSD being displayed accurate within ±1.