MM5791 seven-function,accumulating memory calculator

general description

The single-chip MM5791 calculator was developed using a metal-gate, P-channel enhancement and depletion mode MOS/LSI technology with a primary objective of low end-product cost. A complete calculator as shown in *Figure 1* requires only the MM5791, a keyboard, DS8874 digit driver, NSA1198 or NSA1298 LED display and a 9V battery.

Keyboard decoding and key debounce circuitry, all clocks and timing generation, power-on clear, display turnoff and 7-segment output display decoding are included on-chip and require no external components. Segments can usually be driven directly from the MM5791, as it typically sources 8.5 mA of peak current. The left-most, or 9th digit is used to indicate memory in use or the negative sign of an eight digit number.

Leading zero supression and a floating negative sign allows convenient reading of the display and conserves power. The DS8874 digit driver is capable of sensing a low battery voltage and providing a signal during the left-most digit 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 after approximately 25 seconds is included.

The Ready output signal is used to indicate calculator status. It is useful in providing synchronization information during testing and when the MM5791 is used with other logic devices.

Data ($\overline{D}$) and Shift (CP) outputs are the only two connections required between the MM5791 and the digit driver. This reduces the number of pins on both packages and the amount of interconnect on the printed circuit board. *Figure 3* shows the timing relationships between the MM5791 and DS8874.

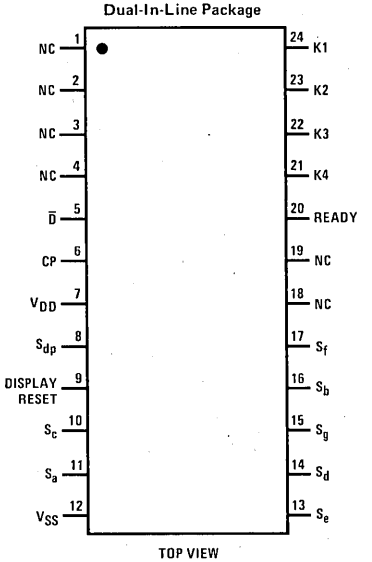
features

- Full 8-digit capacity
- 7-functions (+, −, x, ÷, x^2, $\sqrt{x}$, %)
- Convenient algebraic notation
- Fully protected accumulating memory (M+, M−)
- Automatic constant independent of memory
- Floating input/floating output
- Power-on clear*
- On-chip oscillator*
- Display turnoff after 25 seconds (typical)*
- Direct 9.0V battery compatibility*
- Low system cost
- Direct segment drive of LED display*

*Requires no external components.

connection diagram

Dual-In-Line Package



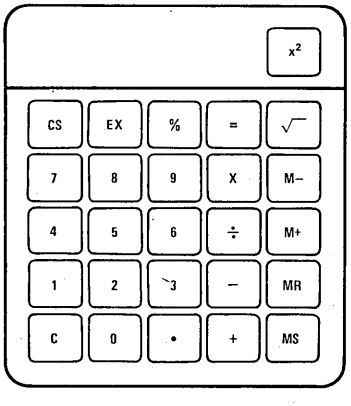
TOP VIEW

Order Number MM5791N

See Package 22

keyboard outline

Sample Keyboard



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 +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

operating voltage range

$6.5V \leq V_{SS} - V_{DD} \leq 9.5V$

dc electrical characteristics

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Current (I_{DD})	$V_{DD} = V_{SS}$ −9.5V, T_A = 25°C		8	15	mA
Keyboard Scan Input Levels (K1–K4)					
Logical High Level (V_{IH})	$V_{DD} = V_{SS}$ −6.5V, $I_{IH} \leq$ −300 μA	V_{SS}−2.5		V_{SS}	V
	$V_{DD} = V_{SS}$ −9.5V, $I_{IH} \leq$ −300 μA	V_{SS}−4.7		V_{SS}	V
Logical Low Level (V_{IL})	$V_{DD} = V_{SS}$ −6.5V	V_{DD}		V_{SS}−5.5	V
	$V_{DD} = V_{SS}$ −9.5V	V_{DD}		V_{SS}−8.0	V
Display Reset Input Levels					
Logical High Level	$V_{DD} = V_{SS}$ − 6.5V	V_{SS}−1.5			V
Logical Low Level	$V_{DD} = V_{SS}$ − 9.5V			V_{DD}+1.5	V
Segment Output Current	T_A = 25°C,				
	$V_{OUT} = V_{SS}$ −3.6V, $V_{DD} = V_{SS}$ −6.5V	−5.0			mA
	$V_{OUT} = V_{SS}$ −5.0V, $V_{DD} = V_{SS}$ −8.0V		−10		mA
	$V_{OUT} = V_{SS}$ −6.5V, $V_{DD} = V_{SS}$ −9.5V			−15	mA
Ready Output	$V_{DD} = V_{SS}$ −6.5V				
Logical High Level	I_{OUT} = −250μA	V_{SS}−1.0			V
Logical Low Level	I_{OUT} = 25μA			V_{SS}−5.0	V
$\overline{D}$ and CP Outputs					
Logical High Level	$V_{DD} = V_{SS}$ −6.5V, $V_{OUT} = V_{SS}$ −2.0V	−220			μA
	$V_{DD} = V_{SS}$ −9.5V, $V_{OUT} = V_{SS}$ −5.0V			−1100	μA
Logical Low Level	$V_{DD} = V_{SS}$ −9.5V, $V_{OUT} = V_{DD}$ +0.8V	100			μA

ac electrical characteristics

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Word Time	*(Figure 2)*	0.53		3.3	ms
Digit Time	*(Figure 2)*	58		367	μs
Interdigit Blanking Time (Segment Outputs)	*(Figure 2)*		4.0		μs
CP and $\overline{D}$ Transition Times					
High to Low	$V_{DD} = V_{SS}$ −6.5V		5	12	μs
Low to High	C_{LOAD} = 50 pF		0.75	1.5	μs
Ready Transition Times					
High to Low	$V_{DD} = V_{SS}$ −6.5		5	20	μs
Low to High	C_{LOAD} = 50 pF		2.0	4.0	μs
Keyboard Scan Inputs					
High to Low	C_{LOAD} = 100 pF		4.0		μs
Low-to-High Transition Time After Key Release					
Key Bounce-Out Stability Time (The time a keyboard scan input must be continuously lower than the maximum logical low level to be accepted as a key closure, or higher than the minimum logical high level to be accepted as a key release.)		6.36		39.6	ms
Display Cutoff Time (The time after the last valid key closure at which the 7 most-significant bits will be blanked.)			25		seconds
Worst Case Calculation Time				200	word times

FUNCTIONAL DESCRIPTION

The MM5791 is a calculator chip which contains four data registers: (1) entry, (2) accumulator, (3) working and (4) memory, each consisting of 8 digits, sign, and decimal point. The entry register is always displayed. It contains digit entries from the keyboard, and results of all functions except M+ and M−. The accumulator is used in all arithmetic functions and stores a copy of the entry register on all results. This allows another number to be entered without losing an intermediate result. Multiply and divide requires three registers to perform the function and save the divisor, or multiplier. The working register is provided to perform these functions in conjunction with the entry and accumulator registers.

The memory register is used only to store a number to be used later. It is fully protected during all operations, and is only modified by depressing a "MS," "M+," or "M−" key. Power on clears all of the registers including the memory register.

The MM5791 performs the "+," "−," "x" and "÷" functions using algebraic notation. This requires the use of a mode register and a terminate flag. The mode register directs the machine to the proper function (add, subtract, multiply or divide) with each new key entry. After the function has been performed, the key entered is used to modify the mode register.

The terminate flag is set on "=" and sometimes on "%" and "C." This signifies the end of the problem. The MM5791 allows for full floating entries and intermediate results.

If the terminate flag is set, a "+," "−," "x" or "÷" key signals the beginning of a new problem. The number being displayed is copied into the accumulator register and the mode register assumes the mode of the key entered. The terminate flag is always reset by the "+," "−," "x" and "÷" keys.

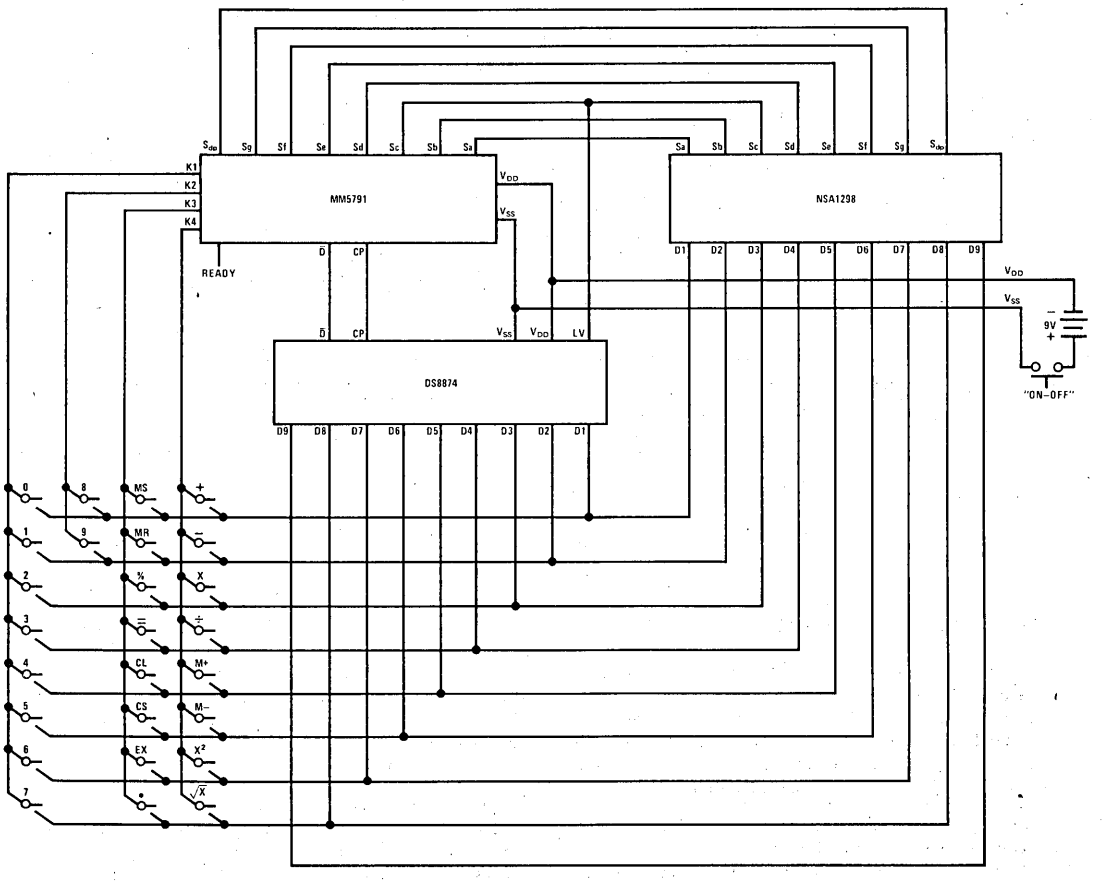


FIGURE 1. Complete Calculator Schematic

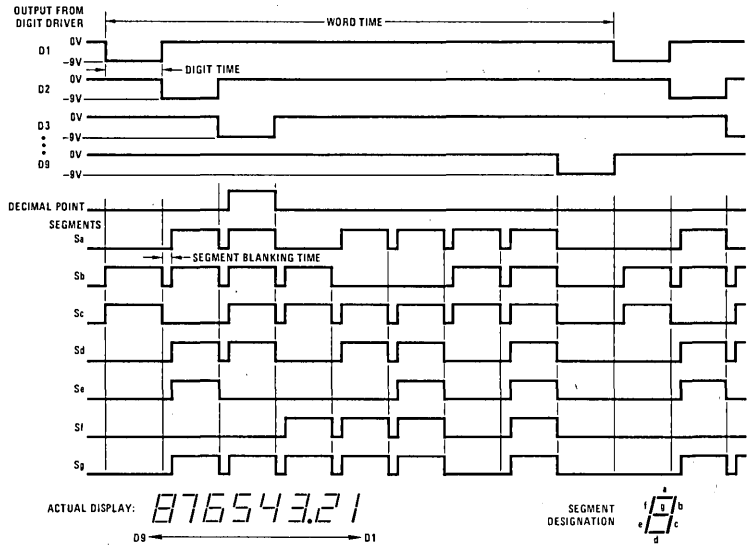


FIGURE 2. Display Timing

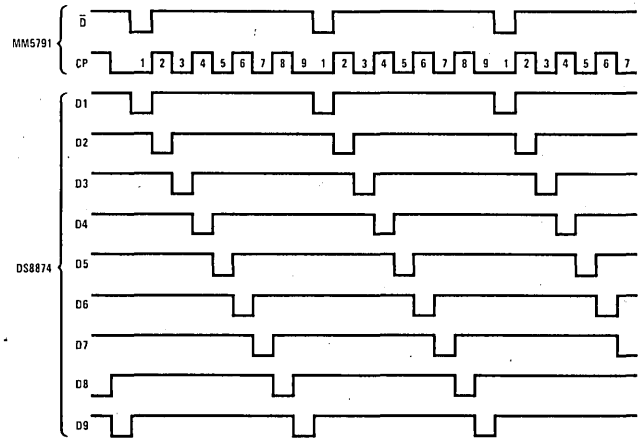


FIGURE 3. Digit Timing

OPERATION IN THE ADD AND SUBTRACT MODE

If the terminate flag is set, an "=" key will result in a constant add/subtract. The number in the accumulator will be added to (or subtracted from) the number being displayed. The result is right-justified and displayed in the entry register. Accumulator and mode registers are not altered, allowing for constant operations.

If the terminate flag is not set and a number has been entered from the keyboard, or memory register, a "+," "–," "x" or "÷" key will result in an addition or subtraction. The entry register will be added to or subtracted from the accumulator and the new running total will be displayed in the entry register and copied into the accumulator register. The mode will be altered according to which key is entered.

If the terminate flag is not set, and a number has not been entered from the keyboard, or memory, a "+," "–," "x" "÷" key will only change the mode register to the new key entry.

If the terminate flag is not set, an "=" key will add/subtract the number being displayed to/from the number in the accumulator register. The number being displayed is transferred to the accumulator, and the result of the operation is displayed in the entry register. The terminate flag is set, conditioning the calculator for constant, add/subtract operation. The number being displayed previous to the "=" key is stored in the accumulator as the constant.

Operation of the "%" key in add/subtract mode, with the terminate flag reset, will multiply the accumulator by the last entry, divide the result by 100, and display it in the entry register. The mode register remains as it was in the add or subtract mode. All of the above is required to perform the percent add on or discount problems. Depression of an "=" key after the "%" key will either tax or discount the original number as a function of the mode register and the last entry.

Operation of the "%" key in add/subtract mode, with the terminate flag set, will shift the decimal point of the number being displayed two places to the left and copy it into the accumulator register. The mode is set to multiply and the terminate flag remains set.

OPERATION IN THE MULTIPLY MODE

If the terminate flag is set, an "=" key will result in a constant multiply operation. The number being displayed is multiplied by the constant stored in the accumulator register. The result is displayed in the entry register and the accumulator and mode registers are not altered, allowing for constant operation. Repeated depressions of the "=" key can be used to raise a number to an integer power, i.e., "C," "C," "5.2," "x," "=," "=," "=," computes 5.2^4.

The constant in multiplication, as well as in addition, subtraction and division is the last number entered. For the sequence: "C," "C," "3," "÷," "4," "x," "2," "=" the constant multiplier for future problems is 2.

If the terminate flag is not set, an "=" key will signal the end of a problem. The number in the display will be multiplied by the contents of the accumulator, and the results will be displayed in the entry register. The number previously in the entry register is stored in the accumulator register and the terminate flag is set.

If the terminate flag is not set, and a number has been entered from the keyboard or memory register, a "+," "–," "x" or "÷" key will result in a multiplication. The number being displayed will be multiplied by the number residing in the accumulator register. The result will be copied into the accumulator and displayed in the entry register. The mode register is up-dated as a function of the key depressed.

Operation of the "%" key while in multiply mode looks exactly the same as an "=" key except the decimal point of the display is shifted two positions to the left before the multiplication takes place.

OPERATION IN THE DIVIDE MODE

If the terminate flag is set, an "=" key will result in constant divide operation. The number being displayed is divided by the constant stored in the accumulator register. The accumulator and mode registers are not altered allowing for constant operations. Repeated depressions of the "=" key will result in repeated divisions by the constant. Thus, it is possible to raise a number to a negative integer power using the sequence: "C," "C," "1," "÷," "No.," "=," "=," etc.

If the terminate flag is not set, an "=" key will signal the end of a problem. The number in the accumulator register will be divided by the number being displayed. The result is transferred to the entry register and displayed. The terminate flag is set and the divisor is stored in the accumulator register.

If the terminate flag is not set, a "+," "–," "x" or "÷" key will result in a division. The number in the accumulator register will be divided by the number being displayed. The results are displayed in the entry register, and a copy of the result is stored in the accumulator. The mode register is modified to reflect the latest key entry.

Operation of the "%" key while in divide mode looks exactly the same as the "=" key except the decimal point of the display is shifted two positions to the left before division takes place.

ERROR CONDITIONS

If any of the operations mentioned above generates a number larger than 9999 9999, an error will occur. An error is indicated by displaying the eight most significant digits and sign with all nine decimal points. The first depression of the "C" key will clear the error condition, and all registers except the memory register.

It is not possible to generate an error during number entry. The ninth and subsequent digits entered are ignored.

DISPLAY TURNOFF AND LEADING ZERO SUPPRESSION

In order to conserve battery power, the MM5791 blanks leading zeros and turns off all but the least significant digit, decimal point and sign after 25 seconds (typical) of no activity. Once the display turns off, any key depression will turn it back on and perform the function indicated. Two depressions of the "CS" key will turn on the display with no change to the machine. If Reset Display is hard-wired to V_{DD}, the display will never turn off.

POWER-ON CONDITION

The MM5791 has an internal power-on clear circuit which clears all registers to zero, places the mode to add and sets the terminate flag. A zero and decimal point are displayed.

KEYBOARD BOUNCE AND NOISE REJECTION

The MM5791 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 negative than the Logical Low Level specified in the electrical specifications. An internal counter is started as a result of the closure. The key operation begins after eleven word times if the Key Input is still at a Logical Low Level. As long as the key is held down (and the Key Input remains low) no further entry is allowed. When the Key Input changes to a Logical High Level, the internal counter starts an eleven word timeout for key release. During both, entry and release timeouts, the Key Inputs are sampled every word time for valid levels. If they are found invalid, the counter is reset and the calculator resumes scanning the keyboard.

READY SIGNAL OPERATIONS

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 timeout is completed and the key entry is accepted as valid, then goes low as indicated in *Figures 5 and 6*. 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.

TEST FEATURES

Several features have been designed into the MM5791 to facilitate testing. One is to allow the key debounce timing to be modified, and the second performs a "segment test" function which turns on all segments for all digit times, with no interdigit blanking. The key bounce time can be reduced from eleven word times to one if a key closure is made between D9 and K2. Similarly the "Segment Test" occurs when a key closure is made between D9 and K3. Closures for test operations are not debounced, and also may occur simultaneously with normal key closures if diodes are used to isolate the D-Lines from each other. The test features are active for every word time the Test switch closure is maintained. These test matrix entries are isolated internally from the normal calculator keys, allowing simultaneous entry of "test" keys and "calculator" keys.

FUNCTION OF KEYS

Some of the keys operate differently when in the data or number entry condition. The MM5791 switches to entry condition when entering numbers and leaves this condition after most function keys. The following paragraphs discuss each of the keys on a full keyboard and the action taken when they are depressed. The earlier paragraphs which discussed the action of "+," "−," "x," "÷" and "%" keys and the examples given in later sections will aid in further explaining these actions.

Clear Key, "CE/C"

While in the number entry condition, one depression will clear the entry register to zero and recall the accumulator for display. The machine then leaves the number entry state.

If the error condition is displayed, one depression will clear the error, and all registers except the memory register. The machine could not be in the number entry condition with the error flag set.

If the error flag is not set and the machine is not in the number entry condition, one depression of "CE/C" key will clear the entry and accumulator registers. It also places the machine in the add mode and sets the terminate flag. The memory register remains unchanged.

Number Keys 0-9

If *not* in the number entry condition, a number key will clear the display and then enter the value of the key into the LSD. The digits are displayed as they are entered and the machine assumes the number entry condition.

If in the number entry condition, the entry register is shifted left one position and the key depressed is entered into the LSD. If there is a number in the most significant digit position (9th) the entry register is then shifted right one position and the entry is lost.

Square Root Key, "$\sqrt{\ }$"

The square root key extracts the square root of the absolute value of the number being displayed in the entry register.

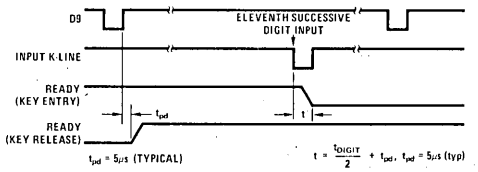


FIGURE 5. Ready Timing

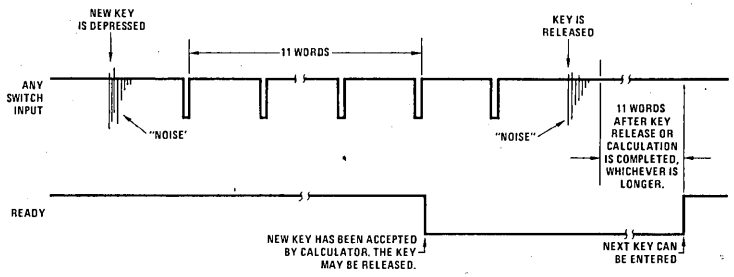


FIGURE 6. Functional Description of Ready Signal and Key Entry

The mode of the calculator remains unchanged. This enables square root operations in the middle of chain calculations. For example:

KEY	DISPLAY	KEY	DISPLAY	KEY	DISPLAY
A	A	A	A	11	11
$\sqrt{}$	$\sqrt{A}$	X	A	+	11.
+	$\sqrt{A}$	B	B	5	5
B	B	$\sqrt{}$	$\sqrt{B}$	=	16.
$\sqrt{}$	$\sqrt{B}$	=	$A\sqrt{B}$	$\sqrt{}$	4.
=	$\sqrt{A}+\sqrt{B}$			6	6.
				=	11
				9	9
				$\sqrt{}$	3.
				=	8.

Square

Depression of the "Square" key copies the number being displayed into the accumulator register, and performs a multiplication. On completion of the square operation, the results are displayed in the entry register, the original number is stored in the accumulator and the mode of the calculator is unchanged. Entering a number to start a new entry will first clear the entry register.

Memory Plus Key, "M+"

When the "M+" key is depressed, the number being displayed is added to the contents of the memory and the results, providing there is no overflow, are placed in the memory. The calculator will be out of the data entry mode.

If an overflow occurs, the contents of the memory are *not* altered. The display shows the eight most significant digits and sign of the results with all nine decimal points.

Memory Minus Key, "M–"

This key operates like the "M+" key only the displayed number is subtracted from memory.

Plus, Minus, Multiply and Divide Keys, "+," "–," "x," "÷"

These keys terminate a number entry, complete the operation designated by the mode register and update the mode register for the next operation. A more detailed explanation of these keys is found in the description of modes.

Equal Key, "="

This key terminates a number entry, complete the operation designated by the mode register and sets the terminate flag.

Percent Key, "%"

Following a clear-all operation or a number entry proceeded by a clear all operation, this key shifts the decimal point of the number being displayed two places to the left, copies it into the accumulating register and establishes the multiply mode.

While in multiply or divide mode, this key shifts the displayed decimal point two places to the left, completes the multiplication or division and sets the terminate flag.

In add or subtract mode, this key shifts the displayed decimal point two places to the left, multiplies the display times the accumulating register, places the product in the entry register and leaves the accumulator register and mode register undisturbed. This permits automatic calculation of net by depression of the "=" key. The terminate flag is not altered.

SAMPLE PROBLEMS

1. Simple addition or subtraction

KEYS	DISPLAY	COMMENTS
C	0	
3	3	Start addition problem
+	3.	Sets add mode
2	2	
+	5.	Completes addition, sets add mode
–	5.	Sets subtraction mode
4.355	4.3 5 5	
=	0.6 4 5	Completes subtraction. Sets mode terminal
+	0.6 4 5	Sets mode terminal. Sets add mode, resets
3.25	3.2 5	Starts Digit Entry
CS	–3.2 5	Changes Sign
4	–3.2 5 4	Continues Digit Entry
+	–2.6 0 9	Completes signed addition, sets add mode
1	1	
=	–1.6 0 9	Completes signed addition, sets terminate mode

2. Constant addition or subtraction (second factor constant)

KEYS	DISPLAY	COMMENTS
3	3	
–	3.	Sets subtract mode
2	2	
+	1.	Completes subtraction, sets Add mode
6	6	
=	7.	Completes addition, saves (6) as constant, sets terminate mode
.5	.5	
=	6.5	Completes constant addition constant=6
7	7	
–	7.	Sets subtraction mode, resets terminate mode

2. Constant addition or subtraction (second factor constant) (continued)

KEYS	DISPLAY	COMMENTS
3	3	
=	4.	Completes subtraction, sets terminate mode, saves 3 as a constant
8	8	
EX	3.	Exchanges entry, and constant
=	−5.	Completes subtraction constant = .8
9	9	
=	1.	Completes subtraction constant = 8

3. Simple multiplication

KEYS	DISPLAY	COMMENTS
3.1	3.1	Start multiplication problem
X	3.1	Sets multiply mode
6	6	
=	1 8.6	Completes multiplication, sets terminate mode

4. Chain multiplication

KEYS	DISPLAY	COMMENTS
3	3	
+	3	Sets add mode
4	4	
X	7.	Completes addition, sets multiply mode
6	6	
−	4 2.	Completes multiplication, sets subtract mode
2	2	
=	4 0.	Completes subtraction, sets terminate mode, saves 2 as constant

5. Constant multiplication

KEYS	DISPLAY	COMMENTS
3	3	
X	3.	Sets multiply mode
4	4	
=	.1 2.	Completes multiplication, saves '4' as constant, sets termination mode

5. Constant multiplication (continued)

KEYS	DISPLAY	COMMENTS
6	6	
=	2 4.	Completes constant multiplication, constant = 4
3	3	
−	3.	Sets subtract mode, resets termination
4.5	4.5	
X	−1.5	Completes subtraction, sets multiply mode
8	8	
CS	−8	Changes sign
=	1 2.	Completes multiplication '−8' as constant, sets termination mode
EX	−8.	Exchanges entry register, and constant
CS	8.	
3	3	
=	3 6.	Completes constant multiplication constant = 12
=	4 3 2.	Completes constant multiplication constant = 12
3	3	
X	3.	Sets multiply mode, resets termination mode
+	3.	Sets add mode. Second function key only modifies mode
−	3.	Sets subtract mode
X	3.	Sets multiply mode
=	9.	Completes multiplication. Sets termination mode

6. Simple division

KEYS	DISPLAY	COMMENTS
4	4	
÷	4.	
3	3	
CS	−3	
=	−1.3 3 3 3 3 3 3	

7. Chain division

KEYS	DISPLAY	COMMENTS
3	3	
÷	3.	
8	8	
+	0.3 7 5	
2	2	
X	2.3 7 5	
3.1	3.1	

8

7. Chain division (continued)

KEYS	DISPLAY	COMMENTS
÷	7.3625	
6	6	
=	1.2270833	

8. Constant division

KEYS	DISPLAY	COMMENTS
6	6	
÷	6.	
2	2	
=	3.	
=	1.5	
15	15	
−	15.	
2	2	
X	13.	
8.3	8.3	
÷	107.9	
3	3	
CS	−3	
EX	107.9	
=	−.02780352	
EX	107.9	
CS	−107.9	
EX	−.02780352	
608.7	608.7	
=	−5.641334 5	

9. Add on and discount problems

KEYS	DISPLAY	COMMENTS
695.99	695.99	
−	695.99	
20	20	
%	139.198	
=	556.792	
+	556.792	
6	6	
%	33.40752	
=	590.19952	
17.95	17.95	
−	17.95	
15	15	
%	2.6925	
+	15.2575	
6	6	
%	0.91545	
=	16.17295	

10. Percent in multiplication and division

KEYS	DISPLAY	COMMENTS
308	308	
X	308.	
5	5	
%	15.4	

10. Percent in multiplication and division (continued)

KEYS	DISPLAY	COMMENTS
500	500	
÷	500.	
4	4	
%	12500.	

11. Memory operations

KEYS	DISPLAY	COMMENTS
6	6	
M+	6.	Memory indicator is activated
3	3	
+	3.	
2	2	
M−	2.	
=	5.	
MR	4.	
3.678	3.678	
CS	−3.678	
M+	−3.678	
X	−3.678	
5	5	
M−	5.	
=	−18.39	
MR	−4.678	
5	5	
MS	5.	
3	3	
X	3.	
4	4	
X	12.	
MR	5.	
=	60.	
0	0	
MS	0.	Memory indicator turned off when contents equal zero

12. Square root problems

KEYS	DISPLAY	COMMENTS
3	3	
$\sqrt{}$	1.7320508	
+	1.7320508	
4	4	
$\sqrt{}$	2.	
=	3.7320508	
7	7	
+	7.	
8	8	
=	15.	
$\sqrt{}$	3.8729833	

13. Square problems

KEYS	DISPLAY	COMMENTS
72	72	
x^2	5184.	