MM5734 8-function accumulating memory calculator

general description

The single-chip MM5734 calculator was developed using a metal-gate P-channel enhancement and depletion mode MOS/LSI technology with a primary object of low end-product cost. A complete calculator as shown in *Figure 1* requires only the MM5734 calculator chip, an X-Y matrix keyboard, an NSA1198 or NSA1298 LED display and a 9V battery.

Keyboard decoding and key debounce circuitry, all clocks and timing generators, power-on clear, and 7-segment output display decoding are included on-chip, and require no external components. Segments and digits can usually be driven directly from the MM5734, as the segments typically source 8 mA of peak current and the digit drivers sink 20 mA min.

Leading zero suppression and a floating negative sign allow convenient reading of the display and conserve power. The MM5734 is capable of sensing a low battery voltage and indicates this by displaying a decimal point in digit eight. Up to 8-digits for positive numbers and 7 for negative numbers can be displayed, with the negative sign displayed in the 8th position. Typical current drain of a complete calculator displaying five "5's" is 25 mA.

The MM5734 is capable of decoding a keyboard matrix as shown in *Figure 1.* Three possible models are shown in *Figure 2. Figure 2(c)* illustrates a keyboard scheme which includes all 8 functions with only 23 keys by using a function key (F).

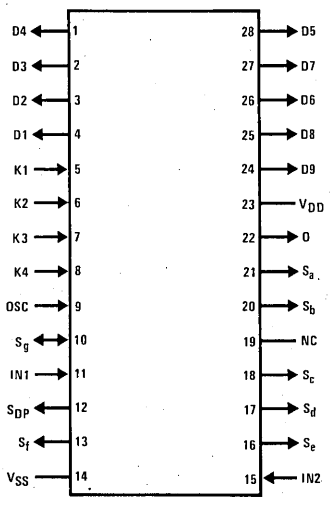
features

- 8-digit, (7-negative), capacity
- 8 functions (+, −, X, ÷, X^2, $\sqrt{X}$, 1/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*
- Direct 9V battery compatibility
- Low system cost
- Direct digit drive of LED display
- Low cost X-Y keyboard matrix

*Requires no external components

connection diagram

Dual-In-Line Package



TOP VIEW

Order Number MM5734N
See Package 23

Pin Description

K1–K4	Keyboard Inputs
IN1, IN2	General Purpose Inputs
OSC	Programmable as External Oscillator
D1–D9	Digit Outputs
S_a–S_g	Segment Outputs
SDP	Decimal Point Segment Output
O	General Purpose Output
V_{DD}	−9 Volts
V_{SS}	0 Volts

keyboard outline

	F*	CS*	%*	D9
	F*	X^2*	EX*	D8
√*	M+*	M−*	÷*	D7
1/X*	MR*	MC*	%*	D6
1/X	√	x^2	÷	D5
7	8	9	×	D4
4	5	6	−	D3
1	2	3	+	D2
C CF	0	•	=	D1
K4	K3	K2	K1	

*Double Function Key

absolute maximum ratings

Volume at Any Pin Relative to V_{SS} (All Other Pins Connected to V_{SS})	V_{SS} +0.3V to V_{SS} −12V
Ambient Operating Time	0°C to +70°C
Ambient Storage Time	−65°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
I_{DD} Operating Supply Current	$V_{DD} = V_{SS} -9.5V$, $T_A = 25°C$		8	15	mA
Keyboard Scan Input Levels CK1 K4					
V_{IH} Logical High Level	$V_{DD} = V_{SS} -6.5V$	$V_{SS}-4.0$		V_{SS}	V
	$V_{DD} = V_{SS} -9.5V$	$V_{SS}-4.0$		V_{SS}	V
V_{IL} Logical Low Level	$V_{DD} = V_{SS} -6.5V$, $I_{IL} \leq -80\mu A$	V_{DD}		$V_{SS}-6.0$	V
	$V_{DD} = V_{SS} -9.5V$, $I_{IL} \leq -80\mu A$	V_{DD}		$V_{SS}-6.3$	V
Segment Output Current	$V_{OUT} = V_{SS} -1.0V$, $V_{DD} = V_{SS} -6.5V$	−2.5			mA
	$V_{OUT} = V_{SS} -5.0V$, $V_{DD} = V_{SS} -8.0V$		−8		mA
	$V_{OUT} = V_{SS} -6.5V$, $V_{DD} = V_{SS} -9.5V$			−12	mA
Digit Output Current					
I_{OH} Logical High Level	$V_{OUT} = V_{SS} -2.0V$, $V_{DD} = V_{SS} -6.5V$	−300			μA
I_{OL} Logical Low Level	$V_{OUT} = V_{SS} -3.0V$	20			mA
Ready Output	$V_{DD} = V_{SS} -6.5V$				
V_{OH} Logical High Level	$I_{OUT} = -550\mu A$	$V_{SS}-1.0$			V
V_{OL} Logical Low Level	$I_{OUT} = 5\mu A$			$V_{DD}+6.0$	V
Keyboard Resistance K1, K4				5	K

ac electrical characteristics

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Display Word Time	*(Figure 3)*	2.9		15.4	ms
Display Digit Time	*(Figure 3)*	0.32		1.71	ms
Interdigit Blanking Time (Segment Outputs)	*(Figure 3)*		175		μs
Ready Transition Times					
High-to-Low	$V_{DD} = V_{SS} -6.5V$			20	μs
Low-to-High	$C_L = 50$ pF			1	μs
Digit Output Transition Times					
High-to-Low	$C_L = 100$ pF		8		μs
Low-to-High			3		μs
Keyboard Inputs High-to-Low Transition Time After Key Release	$C_L = 25$ pF		6		μs
Key Bounce-Out Stability Time (The time a keyboard 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.)		11.7		61.7	ms
Worst-Case Calculation Time				0.56	s

functional description

The MM5734 is a calculator chip which contains five data registers: (1) entry, (2) accumulator, (3) 2 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. A second working register is used to store the constant in chain operations while performing X^2 or 1/X. This allows chain operation using X^2, 1/X and $\sqrt{X}$.

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 MM5734 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 MM5734 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.

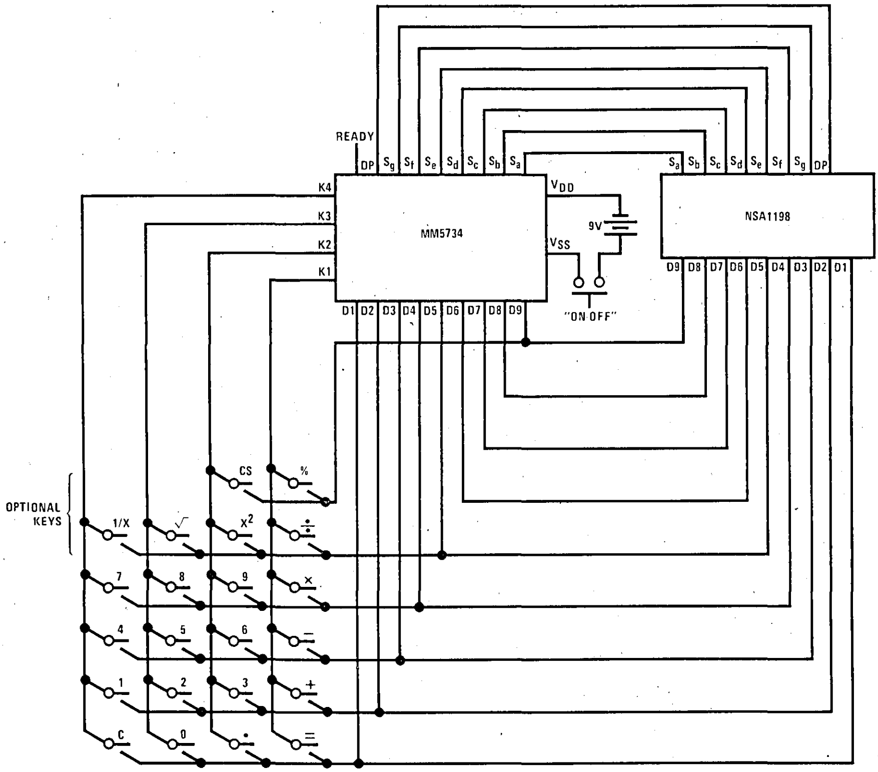


FIGURE 1A. Complete Calculator Schematic

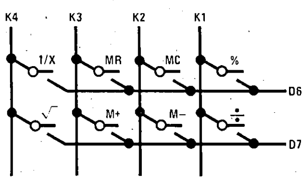


FIGURE 1(b). Optional Keys

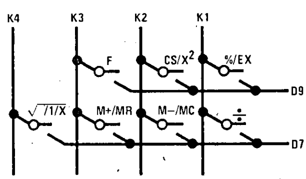


FIGURE 1(c). Optional Keys

OPERATION IN THE ADD AND SUBTRACT MODE

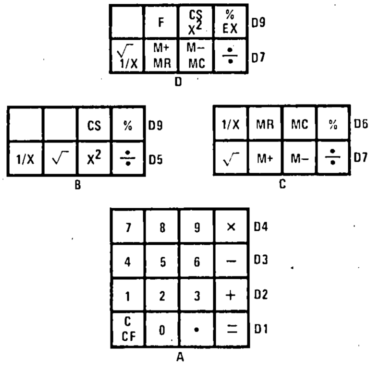


FIGURE 2

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/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 updated 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 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 99999999, an error will occur. An error is indicated by displaying the 8 most significant digits and sign with all 9 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.

Leading Zero Suppression and Negative Sign

In order to conserve battery power, the MM5734 blanks leading zeros on all numbers displayed. No more than 7 decimal digits are permitted. The MM5734 displays 8 digits for positive numbers, and 7 digits negative, allowing the 8-digit position for a negative sign. The negative sign floats to the left of the most significant digit on numbers containing less than 7 digits.

Power-On Condition

The MM5734 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 MM5734 is designed to interface with most low cost keyboards, which are often the least desirable from a false or multiple entry standpoint. A simple X-Y keyboard matrix can be used with all the necessary decoding accomplished within this MM5734.

A key closure is sensed by the calculator chip when one of the key inputs, K1, K2, K3, 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 11 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 11 word timeout for key release. During both, entry and release timeouts, the key inputs are sampled during every display period for valid levels. If they are found invalid, the counter is reset and the calculator resumes scanning the keyboard.

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. 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.

Function of Keys

Some of the keys operate differently when in the data or number entry condition. The MM5734 switches to entry condition when entering numbers and leaves this condition after most function keys. The following paragraphs which discussed the action of "+," "–," "X," "÷" and "%" keys and the examples given in later sections will act in further explaining these actions.

Clear Key, "CE/C"

While in the number entry condition, one depression will clear the entry register to zero. 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. Digits entered after 8 digits positive, or 7 digits negative, will be ignored. Digits entered after 7 decimal digits are displayed will also be ignored.

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

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

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 "X^2" key squares the number in the display register, and displays the results. The mode of the calculator remains unchanged. This enables square operations in the middle of chain calculations.

Inverse

Depression of the "1/X" key takes the inverse of the number in the display register and displays the results. The mode of the calculator remains unchanged. This enables inverse operations in the middle of chain calculations.

F Key (Function Key)

The "F" key translates the following key depressed to this code of the key below it, *Figure 2*, if it is a DOUBLE FUNCTION KEY. If the CLEAR KEY is the following key, the FUNCTION CONDITION is removed leaving the calculator in its previous mode.

SQUARE PROBLEMS

KEYS	DISPLAY	COMMENTS
72	72.	
X^2	5184.	Squares display
7	7.	
CS	−7.	
X^2	49.	Squares minus numbers
+	49.	Chain capabilities
8	8.	
X^2	64.	Squares display (mode unchanged)
=	113.	Completes addition, terminates problems

INVERSE PROBLEMS

KEY	DISPLAY	COMMENTS
5	5.	
1/X	0.2	Takes inverse of display
4	4.	
1/X	0.25	Takes inverse
+		
8	8	
1/X	0.125	Takes inverse (mode unchanged)
=	0.375	Completes addition, terminates problem