MM5737 calculator—8-digit, 4-function, floating decimal point

general description

The MM5737 single-chip calculator was developed using a metal gate, P-channel, enhancement and depletion mode MOS process with low end-product cost as the primary objective. A complete calculator, as shown in *Figure 1*, requires only a keyboard, DM8864 digit driver, nine digit LED display and a 9V battery with appropriate hardware.

Keyboard decoding and key debounce circuitry, all clock and timing generation and output 7-segment display decoding are all included on-chip and require no external discrete components. LED segments can be driven directly from the MM5737 as it typically sources 8.0 mA of peak current. [Note: The typical duty cycle of each digit is 0.111; average LED segment current is therefore approximately 0.111 (8.0 mA), or 0.89 mA. Correspondingly, the worst-case average segment current is 0.111 (5.0 mA), or 0.555 mA.] The ninth digit is used for the negative sign of an eight digit number, and as an error indicator. Negative results less than eight digits will have the negative sign displayed one digit to the left of the most-significant-digit (MSD). The DM8864 digit driver is capable of indicating a low battery voltage condition by turning on the ninth digit decimal point—which does not hinder the actual calculator operation.

Leading and trailing zero suppression allows convenient reading of the right justified display and conserves power. Battery life is estimated to be 10 to 20 hours, depending on battery quality, operating schedule and the average number of digits displayed.

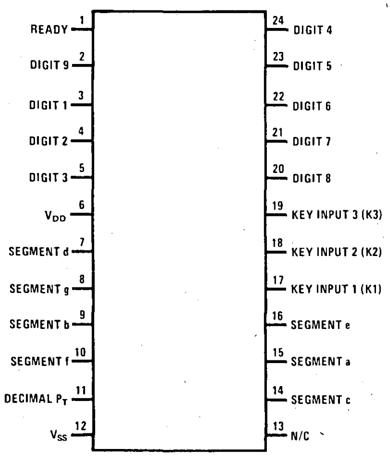
The Ready output signal is used to indicate when the calculator is performing an operation (Table I). It is useful in testing of the device or when the MM5737 is used as part of a larger system and is required to interface with other logic. (Another feature that is important in such applications is the ability to reduce the key debounce time from seven word times to four word times by forcing the Digit 7 output high during Digit 9 time.)

features

- Full 8-digit entry and display capacity
- Four functions (+, −, x, ÷)
- Floating negative sign indicator is always displayed one digit to left of MSD
- Convenient algebraic key entry notation
- Floating point input and output
- Chain operations
- Direct 9V battery compatibility; low power
- Direct interface to LED segments
- No external components are required other than display digit driver, keyboard and LED display for complete calculator
- Overflow and divide-by-zero error indication
- Right justified entry and results, with leading and trailing zero suppression

connection diagram

Dual-In-Line Package



TOP VIEW

Order Number MM5737N
See Package 22

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} − 12.0
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

$6.5V \leq V_{SS} - V_{DD} \leq 9.5V$
(V_{SS} always defined as 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°C		8.0	14.0	mA
Keyboard Scan Input Levels (K1, K2 and K3)					
Logical High Level (V_{IH})	V_{SS} −6.5V ≤ V_{DD} ≤ V_{SS} −9.5V	V_{SS}−2.5			V
Logical Low Level (V_{IL})	V_{DD} = V_{SS} −6.5V			V_{SS}−5.0	V
	V_{DD} = V_{SS} −9.5V			V_{SS}−6.0	V
Digit Output Levels (Note 1)					
Logical High Level (V_{OH})	V_{SS} −6.5V ≤ V_{DD} ≤ V_{SS} −9.5V	V_{SS}−1.5			V
Logical Low Level (V_{OL})	V_{DD} = V_{SS} −6.5V			V_{SS}−6.0	V
	V_{DD} = V_{SS} −9.5V			V_{SS}−7.0	V
Segment Output Current (Sa through Sg and Decimal Point)	T_A = 25°C				
	V_{OUT} = V_{SS} −3.8V, V_{DD} = V_{SS} −6.5V	−5.0	−8.0		mA
	V_{OUT} = V_{SS} −5.0V, V_{DD} = V_{SS} −8.0V		−10.0		mA
	V_{OUT} = V_{SS} −6.5V, V_{DD} = V_{SS} −9.5V			−15.0	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} = 10μA			V_{DD}+1.0	V

Note 1: With digit connected through key to K-line and to DM8864.

ac electrical characteristics

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Word Time *(Figure 2)*		0.63	1.5	5.2	ms
Digit Time *(Figure 2)*		70	170	580	μs
Interdigit Blanking Time *(Figure 2)*			4		μs
Digit Output Transition Times (t_{RISE} and t_{FALL})	C_{LOAD} = 100 pF		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	60	140	480	μs
High to Low Level (t_{PDL})	C_{LOAD} = 100 pF	0.06	0.5	1.5	ms
Key Bounce-out Stability Time (The time a keyboard input must be continuously higher than the minimum logical high level to be accepted as a key closure, or continuously lower than the maximum logical low level to be accepted as a key release.)		4.2	10.5	35	ms
Calculation Time for 99999999 ÷ 1 = 99999999		90	220	760	ms

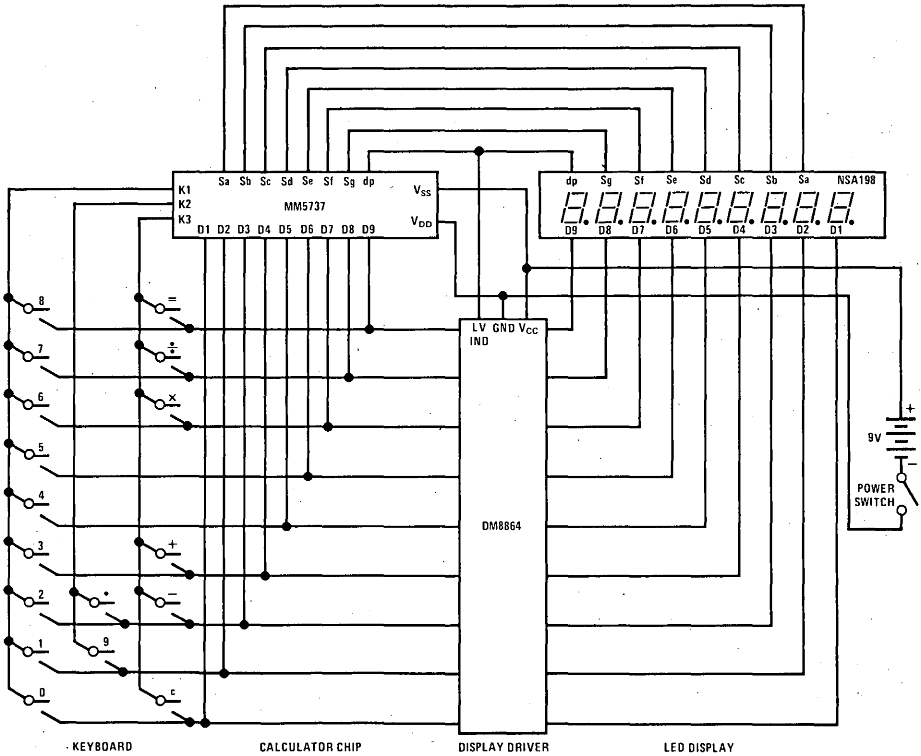


FIGURE 1. Complete Calculator Schematic

TABLE I. Ready Signal Description

CALCULATOR FUNCTION	READY SIGNAL
Idle	*READY* is quiescently at a Logical High Level ($\sim V_{SS}$).
Key Entry and Functional Operation	When a key is depressed, the bounce-out stability timer is initiated. *READY* remains high until the bounce-out time is completed and the key is entered, at which time it changes to a Logical Low Level ($\sim V_{DD}$).
Key Release and Return to Idle	*READY* remains low until key release is debounced and the calculator returns to the idle state. The low to high transition signals the return to idle. (The display may lag the *READY* by up to eight word times.)

KEY INPUT BOUNCE AND NOISE REJECTION

The MM5737 calculator chip is designed to interface with low cost keyboards, which are often the least desirable from a noise and false entry standpoint.

A key closure is sensed by the calculator chip when one of the Key Input Lines, K1, K2 or K3 is forced more positive than the Logical High Level specified in the Electrical Specifications. At the instant of closure, an internal "Key Bounce-out Stability Time" counter is started. Any significant voltage perturbation occurring on the switched key input during timeout will reset the timer. Hence, a key is not accepted as a valid entry until noise or ringing has stopped and the stability time counter has timed out. Noise that persists will inhibit key entry indefinitely. Key release is timed in the same manner.

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 MM5737 defines a series contact resistance up to 50 kΩ as a valid key closure, providing an optimum interface to that type of keyboard as well as more conventional types.

ERROR CONDITIONS

In the event of an overflow, the MM5737 will display an "E" in the leftmost digit and at least seven of the significant digits of the answer. Division by zero results in an "E" with eight trailing zeroes. Once in an error condition, all keys except the clear key are ignored.

KEY OPERATIONS

Clear Key

Operation after a number entry clears the entry and displays a previous result. Second depression clears all registers and displays a zero without decimal point in the LSD. Operation after a function key (+, −, x, ÷ or =) clears all registers and displays a zero without decimal point. Two depressions are always required after power is applied.

Number Entries

First entry clears the display register and enters the number into the least significant digit (LSD) of the display register. Second through eighth entry shifts the display register left one digit and enters the number into the LSD. The ninth, and subsequent entries, are ignored and no error condition is generated. Because only seven positions are allowed to follow the decimal point, the eighth and subsequent entries after a decimal point entry are ignored.

Decimal Point

First depression of this key in a number entry will enter a decimal point in the LSD position of the display register. Subsequent depressions of the decimal point key before any function key will be ignored.

Add, Subtract, Multiply or Divide Keys

First depression after a number entry will terminate the entry, perform the previously recorded operation, if any, and record the function key depressed as the next operation to be performed after another number entry. Subsequent depressions of any function key, without an interceding number or decimal point entry will supersede the previous function as the next to be performed. After an equal key, the displayed result of the equal operation will be re-entered and the function key depressed will become the next operation to be performed after a number entry is followed by another function key (including equal).

Equal

First depression after a number entry will terminate the entry, perform the previously recorded operation and record the fact that an equal key has been depressed. Depression after the add, subtract or divide keys, without an interceding number or decimal point entry, will be ignored. After a multiply key, the number being displayed will be squared.

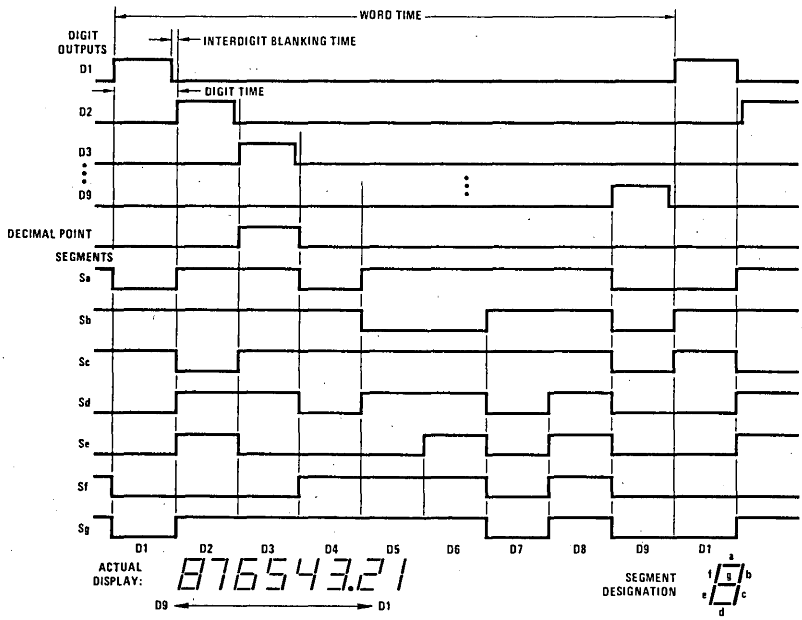


FIGURE 2. Display Timing Diagram

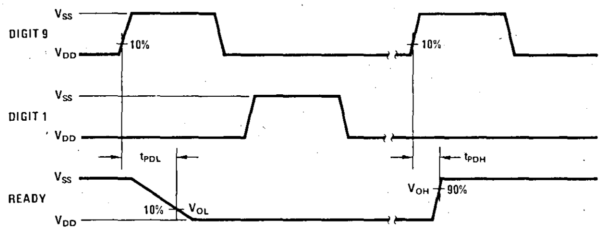


FIGURE 3. Ready Output Timing

sample problems

I. Single Calculations

5 x 3.14 = 15.7

Key	Display	Comments
C		Two clears are required after power-up.
C	0	
5	5	
x	5	
3	3	
.	3.	
1	3.1	
4	3.1 4	
=	1 5.7	

II. Chain Calculations

A. 23.37 + 243.00 − 489.16 = −222.79

Key	Display	Comments
C		
C	0	
23.37	2 3.3 7	
+	2 3.3 7	
243	2 4 3	
x (Wrong Function Key)	2 6 6.3 7	Function key completes previously recorded "+" operation.
−	2 6 6.3 7	Wrong "X" function key is updated to "−."
489.17	4 8 9.1 7	
C	2 6 6.3 7	
489.16	4 8 9.1 6	Number entry error is cleared and corrected. Note the
=	−2 2 2.7 9	floating negative sign.

B. Find square root of 169 using a modified Newton approximation method. Let N represent the squared number and X_0 the initial estimate. The first approximation, X_1, is

$X_1 = (N/X_0 + X_0)/2$

If X_0 is 15,

$X_1 = (169/15 + 15)/2$

$X_2 = (169/X_1 + X_1)/2$

$X_3 = (169/X_2 + X_2)/2$, etc.

Key	Display	Comments
C		
C	0	
169	1 6 9	
÷	1 6 9	
15	1 5	
+	1 1.2 6 6 6 6 6	
15	1 5	
÷	2 6.2 6 6 6 6 6	
2	2	
=	1 3.1 3 3 3 3 3	Result is X_1
169	1 6 9	
÷	1 6 9	
13.13	1 3.1 3	Four digits are conveniently remembered

sample problems (con't)

II. Chain Calculations (continued)

Key	Display	Comments
+	12.871287	
13.13	13.13	
÷	26.001287	
2	2	
=	13.000643	Result is X_2, which is usually adequate. If more accuracy is required, continue the iteration.

III. Auto Squaring.

A. $5.25^2 = 27.5625$

Key	Display	Comments
C		
C	0	
5.25	5.25	
x	5.25	
=	27.5625	Number in display register is squared.

B. $5.25^5 = 3988.3798$

Key	Display	Comments
C		
C	0	
5.25	5.25	
x	5.25	
=	27.5625	Auto square = 5.25^2
x	27.5625	
=	759.6914	Auto square = 5.25^4
x	759.6914	
5.25	5.25	
=	3988.3798	Result is 5.25^5