MM5780 educational toy calculator general description

The MM5780 single-chip, educational calculator was developed using a metal gate, P-channel, enhancement and depletion mode MOS process. It was designed with low end-product cost as the primary objective and is directed toward the educational toy market. Besides the MM5780, a complete calculator, as shown in *Figure 1*, requires only a keyboard, "Right" and "Wrong" LED display, a 9V battery and an on/off switch. Keyboard encoding and key debounce circuitry, all clock and timing generation and the capability to drive the two LEDs are all included on-chip and require *no* external discrete components.

The MM5780 educational calculator was designed to be a mathematical aid to school age children. Problems are entered into the machine in algebraic form exactly as they are written across a printed page. The student provides the answer or missing factor and when finished, depresses the Test key. "Right" and "Wrong" outputs provide an indication of the results of the test. If wrong, the student trys the problem again. If correct, he can move on to the next problem. Most problems using +, −, x and ÷ can be learned using this machine. The calculator does not have provisions for remainders in division or negative number entries. A negative result can be entered before the Test key is depressed.

The MM5780 is a low power device which operates directly from a 9V battery. Battery life is estimated to be 10 to 30 hours depending on battery quality and operating schedule.

When the battery voltage falls below an operational level, an internal circuit will disable both indicator outputs; i.e., neither indicator will be on after depression of Test.

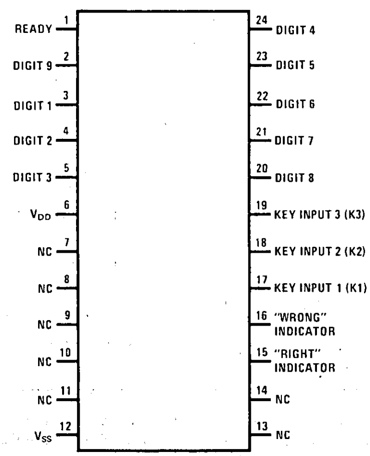
The Ready output signal is used to indicate when the calculator is performing an operation. It is useful in testing of the device or if interfacing with other logic. Another feature that is important in testing is the capability of reducing the key debounce time from seven word times to four word times by forcing the Digit 7 output high during Digit 9 time.

features

- Full 8-digit entry capacity
- Four functions (+, −, x, ÷)
- Convenient algebraic key entry notation
- Floating point input and output
- Chain operations
- Direct 9V battery compatibility; low power
- Direct interface to LED indicators
- No external components required other than keyboard and LED display for complete educational calculator
- Overflow and divide-by-zero error indication
- Low battery voltage sensing

connection diagram

Dual-In-Line Package



TOP VIEW

Order Number MM5780N
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 (Note 1)

$6.5V \leq V_{SS} - V_{DD} \leq 9.5V$
(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°C		8.0	14.0	mA
Keyboard Scan Input Levels (K1, K2 and K3)					
Logical High Level (V_{IH})	$V_{SS}-6.5V \leq V_{DD} \leq V_{SS}-9.5V$	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})	$V_{SS}-6.5V \leq V_{DD} \leq V_{SS}-9.5V$	V_{SS}−1.5			V
Logical Low Level (V_{OL})	$V_{DD} = V_{SS}$−6.5V			V_{SS}−6.0	V
	$V_{DD} = V_{SS}$−9.5V			V_{SS}−7.0	V
Indicator Output Current					
Source Current	T_A = 25°C				
	$V_{OUT} = V_{SS}$−4.5, $V_{DD} = V_{SS}$−6.5V	−10.0	−15.0		mA
	$V_{OUT} = V_{SS}$−4.8, $V_{DD} = V_{SS}$−9.5V		−25.0	−32.0	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

ac electrical characteristics (*Figure 2*)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Word Time		0.6	1.5	5.2	ms
Digit Time		70	170	580	μs
Keyboard Input (K1, K2, K3) High to Low Transition Time After Key Release	C_{LOAD} = 100 pF		4		μs
Ready Propagation Time	C_{LOAD} = 100 pF				
Low to High Level (t_{PDH})		60	140	480	μs
High to Low Level (t_{PDL})			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	35.0	ms
Calculation Time for 99999999 ÷ 1 = 99999999		90	220	765	ms

Note 1: The internal low battery voltage sensing circuit will disable both indicator outputs when $V_{SS}-V_{DD}$ falls below a safe operating voltage. That voltage may be less than or greater than 6.5V depending on process variables; the MM5780 will have been tested to operate correctly for any voltage less than 9.5V at which an indicator output is enabled.

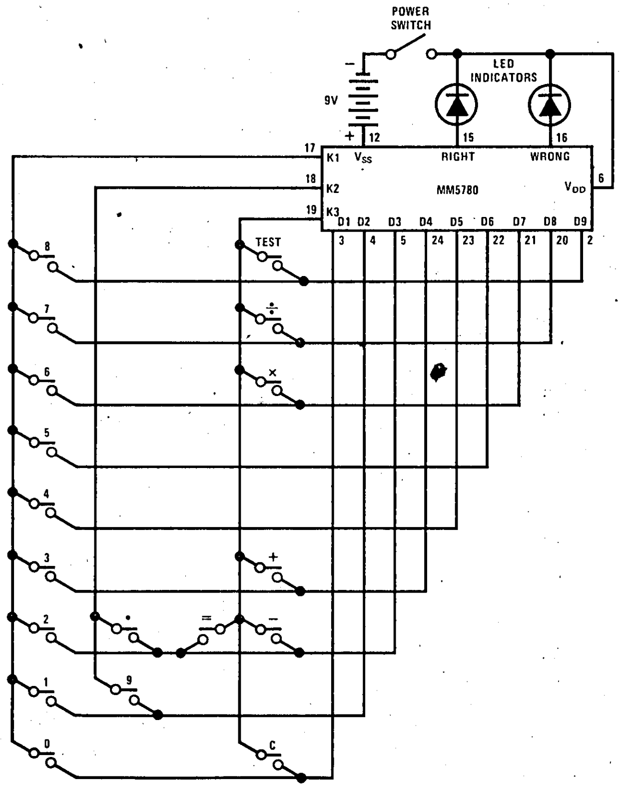


FIGURE 1. Complete Calculator

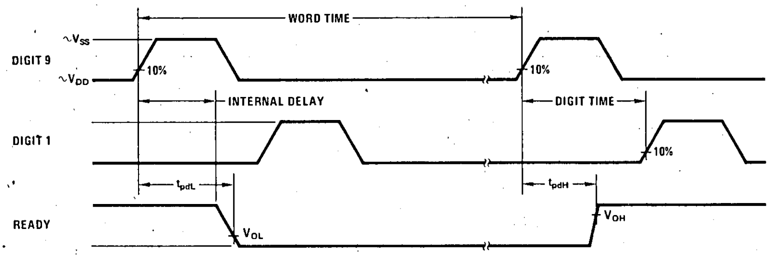


FIGURE 2. Output Timing

KEY INPUT BOUNCE AND NOISE REJECTION

The MM5780 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 are 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 MM5780 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 or divide-by-zero the "Wrong" light will come on and remain on until a Clear key is depressed. Normally the indicator lights are activated only after depression of the TEST key.

KEY OPERATIONS

Clear Key

The Clear key clears all registers to zero and places the machine in an idle state.

Number Entries

First entry clears the entry register and enters the number into the least significant digit (LSD) of the entry register and extinguishes the indicator lights. Second through eighth entry shifts the entry 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

Depression results in a decimal point entry into the entry register.

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. If a function key is depressed after an equal key, the result of the 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 in the entry register will be squared.

Resultant Entries

Results are entered as number entries after an equal key and before the Test key. Results are assumed positive and a plus key should *not* be entered prior to the resultant. Negative results must be preceded by a minus key.

Test

The Test key is used to terminate computations and to initiate a test of the student's answer versus the calculator's answer. If the answers match, the "Right" indicator is enabled, otherwise the "Wrong" indicator is enabled. If the results are incorrect the problem must be worked again from the beginning.

TABLE I. Ready Signal Description

CALCULATOR FUNCTION	READY SIGNAL
Idle	$\overline{READY}$ 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. $\overline{READY}$ 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	$\overline{READY}$ 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.

TABLE II. Indicator Truth Table

CALCULATOR CONDITION	INDICATOR OUTPUT	
	PIN 15	PIN 16
Test was last key depressed with correct answer entered.	HIGH	LOW
Test was last key depressed with incorrect answer entered or the problem has resulted in an error or overflow condition.	LOW	HIGH
Any key other than Test was last depressed and calculator is not in an error or overflow condition.	LOW	LOW
Clear was last key depressed.	LOW	LOW
The battery supply voltage has fallen below a valid operating voltage for the MM5780. Independent of keys depressed.	LOW	LOW

sample problems

I. Simple Addition: 4 + 5 = ?

Key	Display	Comments
C		
C	N O N E	Clear necessary on power-up
4	N O N E	
+	N O N E	
5	N O N E	
=	N O N E	
8	N O N E	Answer supplied
TEST	W R O N G	Wrong answer
4	N O N E	Indicator goes out
+	N O N E	
5	N O N E	
=	N O N E	
9	N O N E	
TEST	R I G H T	

II. Missing Factor Addition: 6 + ? = 11

Key	Display	Comments
6	N O N E	Indicator goes out
+	N O N E	
5	N O N E	Missing factor supplied
=	N O N E	
11	N O N E	
TEST	R I G H T	

III. Subtraction: 4 – 7 = ?

Key	Display	Comments
4	N O N E	Indicator goes out
–	N O N E	
7	N O N E	
=	N O N E	
–	N O N E	
3	N O N E	Negative answer supplied
TEST	R I G H T	

IV. Multiplication: 7 x 3 = ?

Key	Display	Comments
7	N O N E	Indicator goes out
x	N O N E	
3	N O N E	
=	N O N E	
21	N O N E	Answer supplied
TEST	R I G H T	

sample problems (con't)

V. Missing Factor Multiplication: 6 x ? = 12

Key	Display	Comments
6	N O N E	Indicator goes out
x	N O N E	
3	N O N E	Missing factor supplied
=	N O N E	
12	N O N E	
TEST	W R O N G	Incorrect
6	N O N E	Indicator goes out
x	N O N E	
2	N O N E	Missing factor supplied
=	N O N E	
12	N O N E	
TEST	R I G H T	

VI. Division: 15 ÷ 3 = ?

Key	Display	Comments
15	N O N E	Indicator goes out
÷	N O N E	
3	N O N E	
=	N O N E	
5	N O N E	Answer supplied
TEST	R I G H T	

VII. Complex Chain: (6 + 2 − 10) x 3 = ?

Key	Display	Comments
6	N O N E	Indicator goes out
+	N O N E	
2	N O N E	
−	N O N E	
10	N O N E	
x	N O N E	
3	N O N E	
=	N O N E	
−	N O N E	
6	N O N E	Negative answer supplied
TEST	R I G H T	