



MM5764 conversion calculator

general description

The single-chip MM5764 Conversion Calculator was developed using a metal-gate, P-channel enhancement and depletion mode MOS/LSI technology with low end-product cost as a primary objective. A complete calculator as shown in *Figure 1* requires only the MM5764, a keyboard, DS8864 digit driver, NSA1298 LED display, 9V battery and 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 MM5764, 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 0.104 (8.5 mA), or 0.9 mA average. Correspondingly the worst-case average segment current is 0.104 (5.0 mA), or 0.52 mA.] The ninth digit (left-most) is used for the negative sign, or the decimal point of a number less than unity.

An internal power-on clear circuit is included that 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 DS8864 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 25 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 for testing or applications where the MM5764 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 as shown in Table I. There is an automatic constant feature.

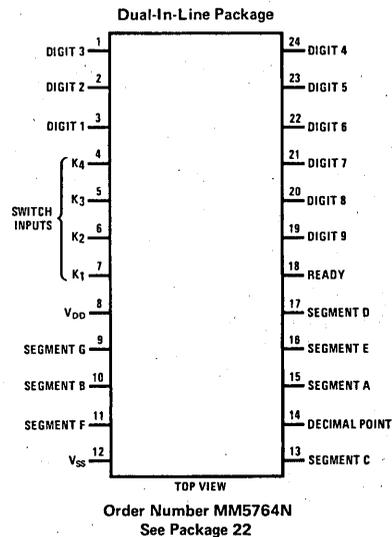
The user has access to five registers designated X, T, A, K and M. The X-register is used for keyboard entry and display. The T and A-registers are used in multiply/divide and add/subtract calculations, respectively. M is an accumulating storage memory. The K-register is used to store a user defined conversion constant.

Data is entered into the calculator in floating point business notation. All entries and results are displayed left justified with insignificant zeros to the right of the decimal point suppressed. All intermediate results of a chain calculation are floating point. Terminating keys "=", "%", and "=+" round the displayed result to two decimal places.

features

- Full 8-digit entry and display calculator
- Arithmetic functions: +, -, x, ÷, =, %, 1/x
- Percent mark-up and discount
- Twenty automatic conversions
- A user definable conversion key
- Change sign and "π" keys
- Accumulating memory: MR, M+, =+, MC
- Square root
- Auto constant
- Business notation
 - +, - "adding machine" notation
 - x, ÷, = algebraic notation
- Automatic power-on clear
- Automatic display cutoff
- Direct 9V battery compatibility; low power

connection diagram



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 $0^{\circ}C$ 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

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

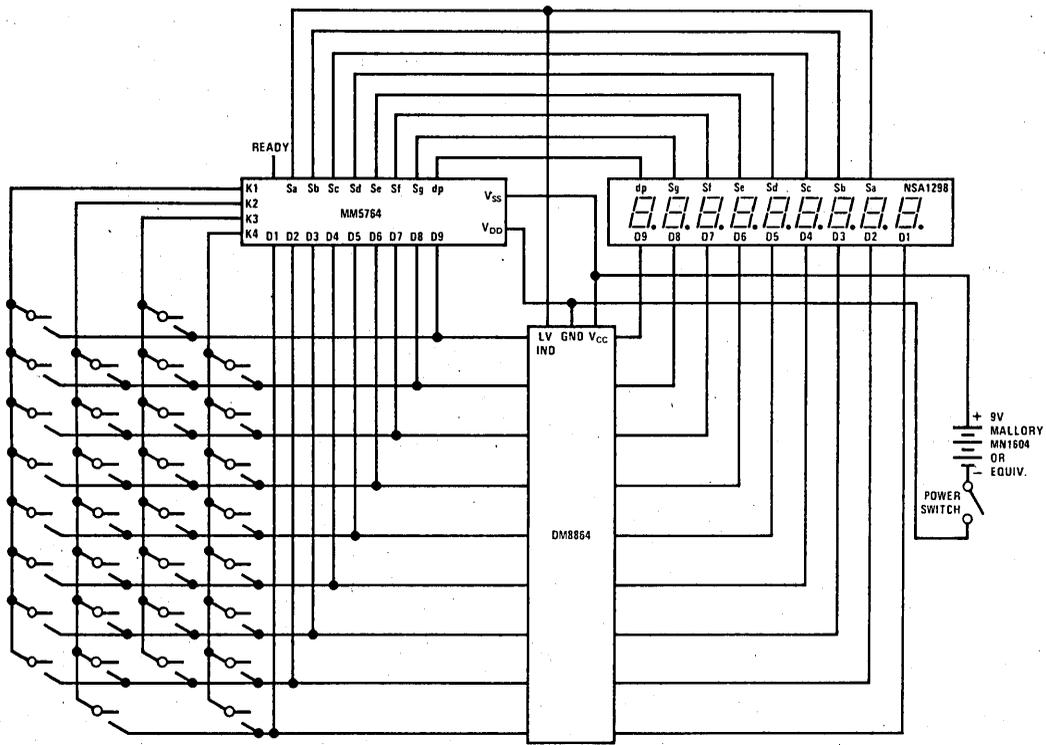
V_{SS} always defined as most positive supply voltage.

dc electrical characteristics

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Current (I_{DD})	$V_{DD} = V_{SS} - 9.5V$, $T_A = 25^{\circ}C$			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
Logical Low Level	$V_{DD} = V_{SS} - 6.5V$ $V_{DD} = V_{SS} - 9.5V$			$V_{SS} - 5.0$ $V_{SS} - 6.0$	V 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		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	0.8	2.0	ms
Digit Time (Figure 2)		36	89	222	μs
Segment Blanking Time (Figure 2)		2	5.5	14	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	7.2	18	ms
Key Release		5.1	12.8	32	ms
Display Cutoff Time (The time after the last valid key closure that all numbers will be blanked and all decimal points displayed.)		10	25	63	sec



KEYBOARD
 Note: See Table II for Key Matrix Designs.

FIGURE 1. Complete Calculator Schematic

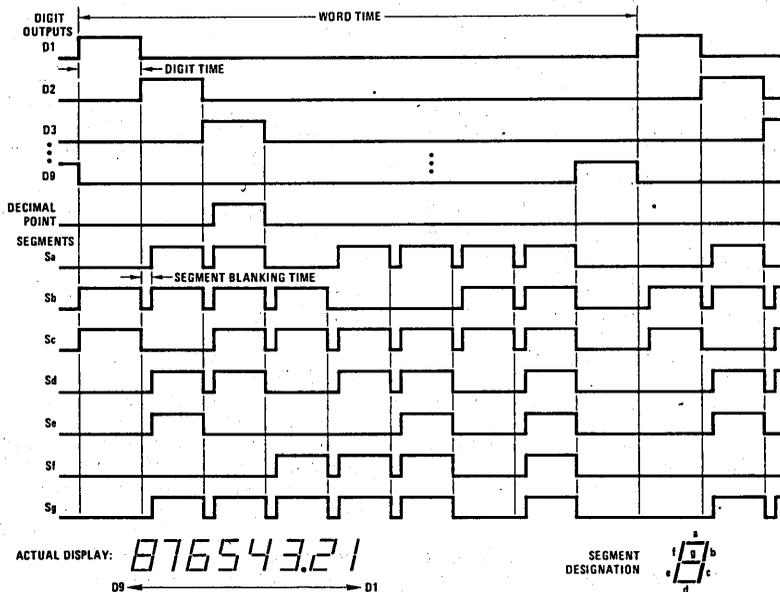


FIGURE 2. Display Timing Diagram

TABLE I. Mode Summary

MODE	KEYS THAT SET MODE	DESCRIPTION (See Calculation Examples)
CONSTANT MULTIPLY	"CLEAR" "="	Depression of an "=", "M+" or "M-" key will multiply the X-register by the T-register and replace X with the product. T remains unchanged.
CHAIN MULTIPLY	"X," following a terminator, or "M+" or "M-" operation	Depression of an "=", "M+" or "M-" key will multiply the X-register by the T-register and place the product in X. T remains unchanged.
CONSTANT DIVIDE	"=" } With calculator "M+" } previously in chain "M-" } divide mode.	Depression of an "=", "M+" or "M-" key will divide the X-register by the T-register and replace X with the quotient. T is unchanged.
CHAIN DIVIDE	"M+" following a terminator or "M-" or "X" operation	Depression of an "=", "M+" or "M-" key will divide the T-register by the X-register, transfer X to T, and place the quotient in X.

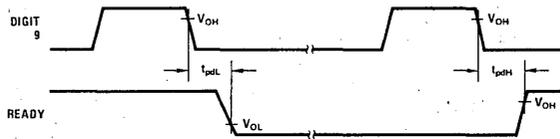


FIGURE 4. Ready Timing

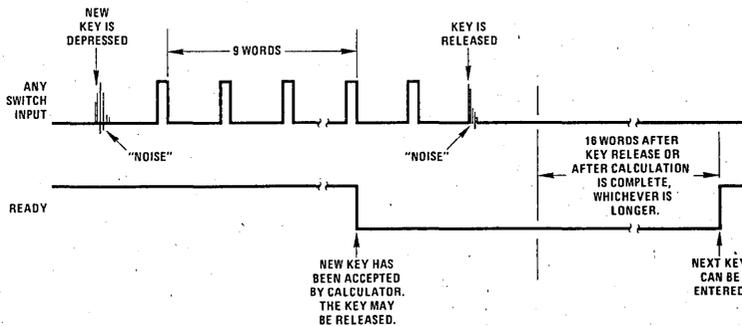


FIGURE 5. Functional Description of Ready Signal and Key Entry.

calculation, the T-register will contain the value used as first factor of the last multiply, or the latest entry if the last operation was a divide.

Table I summarizes the four modes.

KEY OPERATIONS

(Note: X-register is always displayed.)

Clear Key, "C"

Following a number key, it clears only the X-register (clear entry); after any other key, it clears registers X, A and T.

Number Entries

The first entry clears the X-register and enters the number as the LSD of X. Second through eighth entries (excluding a decimal point) are entered one digit to the right of the previous number. The ninth, and subsequent entries, are ignored. First entry after a "+,"

"-" or "M+" following a "+" or "-" key transfers the existing number in the X-register to the A-register before clearing and placing the new entry in X.

Conversion Functions

With the exception of the six single function conversion keys, all conversions are preceded by either the shift key, "→," or the reverse conversion key, "←." Depression of the appropriate conversion key replaces the value in the X-register with a converted result, as summarized in Table II. The six single function keys (inches → mm, "inches → cm," "ft → inches," "ft → m," "yds → m" and "miles → km") do not need to be preceded by the shift key, "→," for forward conversions. Only the X-register is affected by a conversion operation.

Constant Store Key, "KS"

The value of X is copied into the K-register. Following a forward conversion key, "→," X is multiplied by K and the product stored in X; following a "←" key, X is divided by K, and the quotient is stored in X.

Decimal Point, "."

As the first depression of a number entry, it clears the X-register and places a point in the leftmost digit. If the previous key was a number, it enters a decimal point to the right of the last number entered. Following a "+", "-", or those keys preceding a "M+" key, the X-register is transferred to A, cleared and a decimal point entered in the leftmost digit. The last decimal point depression in a single number entry is accepted as the valid point.

Change Sign Key, "CS"

Changes sign of register X.

Addition Key, "+"

If the previous key was not a "+" or "-" key, the number in the A-register is added to the X-register, X is transferred to A, and the sum is stored in X. When the last key was a "+" or "-" key, the number in A is added to the number in X without destroying the value of A. The sum is stored in X.

Subtraction Key, "-"

If the previous key was not a "+" or "-" key, the number in the X-register is subtracted from the number in the A-register, X is transferred to A, and the difference is stored in X. When the last key was a "+" or "-" key, the number in A is subtracted from X without destroying the value of A. The result is stored in X.

Multiplication Key, "x"

If there has not been an "x" or "÷" key since the last terminator key ("=", "+", "%"), the value of the X-register is copied into the T-register and the calculator is set to the chain multiply mode. In a chain calculation in which there has been a "x" key since the last terminator or "÷" key, X is multiplied by T and the resulting product is stored in both X and T; if a "÷" key has occurred since the last terminator or "x" key, depression of "x" will divide the T-register by the X-register, with the quotient stored in both X and T.

Division Key, "÷"

If there has not been an "x" or "÷" key since the last terminator key ("=", "+", "%"), the value of the X-register is copied into the T-register and the calculator is set to the chain divide mode. In a chain calculation if a "x" key has occurred since the last terminator or "÷" key, X is multiplied by T and the product is stored in both X and T; if a "÷" key has occurred since the last terminator or "x" key, depression of "÷" will divide the T-register by the X-register, with the quotient stored in both X and T.

Equal Key, "="

In the chain multiply mode, the value in the X-register is multiplied by the T-register with the product stored

in X. Register T remains unchanged. In the chain divide mode, depression of "=" will divide T by X, transfer X to T, and place the quotient in X. If the calculator is in constant multiply, "=" will multiply X by T, place the product in X and retain T. For constant divide, the X-register is divided by T, the quotient is stored in X; T is unchanged.

The "=" key always rounds the answer stored in X to two places to the right of the decimal point, and clears register A.

Per Cent Key, "%"

This key acts exactly like the "=" key except the value of X is divided by 100 and copied in register A before performing the required operation. The result stored in X is rounded to two decimal positions.

Memory Plus Key, "M+"

The number in the X-register is accumulated in the M-register. Registers X and A are not changed, so the repeat addition or subtraction conditions that existed before accumulation to memory remain valid.

Memory Recall Key, "MR"

The value of register M is copied into the X-register. If the preceding key was a "+", "-", or "M+" followed by "+" or "-", the value of X is transferred to the A-register before M is copied into it.

Memory Clear Key, "MC"

The M-register is cleared, without affecting any other registers.

Reciprocal Function, "1/x"

If the number entry key "1" is preceded by either the forward or reverse conversion shift keys, "→" or "←," a non-zero value of X is replaced by its reciprocal. Registers A, T, K and M are not altered.

Square Root Function, " \sqrt{x} "

If the number entry key "2" is preceded by either the forward or reverse conversion shift keys, "→" or "←," the absolute value of X is replaced by its square root. Registers A, T, K and M are unaltered.

Pi-function, "π"

If the decimal point entry key is preceded by either the forward or reverse conversion shift keys, "→" or "←," the value of X is replaced by the constant 3.1415927.

Equal Plus Key "=+"

This key acts exactly like the "=" key followed by a "M+" key. The multiply or divide is executed the result is rounded to two places then the rounded result is added to the Memory.

TABLE II. Summary of Key Functions

KEY MATRIX DESIGNATION	PRIMARY KEY FUNCTION	IF PRECEDED BY "→" SHIFT KEY	IF PRECEDED BY "←" SHIFT KEY
K1-D1	N/C	—	—
K1-D2	Minus, "-"	"-"	"-"
K1-D3	Plus, "+"	"+"	"+"
K1-D4	Divide, "÷"	"÷"	"÷"
K1-D5	Multiply, "x"	"x"	"x"
K1-D6	Constant Store, "KS" Constant Conversion	$X_0 \cdot K \rightarrow X$	$X_0 \div K \rightarrow X$
K1-D7	Ft → in	$X_0 \cdot (12) \rightarrow X$	$X_0 \div (12) \rightarrow X$
K1-D8	In → mm	$X_0 \cdot (25.4) \rightarrow X$	$X_0 \div (25.4) \rightarrow X$
K1-D9	In → cm	$X_0 \cdot (2.54) \rightarrow X$	$X_0 \div (2.54) \rightarrow X$
K2-D1	Mile → km	$X_0 \cdot (1.609344) \rightarrow X$	$X_0 \div (1.609344) \rightarrow X$
K2-D2	Ft → m	$X_0 \cdot (0.3048) \rightarrow X$	$X_0 \div (0.3048) \rightarrow X$
K2-D3	Forward Shift, "→"	"→"	"→"
K2-D4	Memory Clear, "MC"	"MC"	"MC"
K2-D5	Yard → m	$X_0 \cdot (0.9144) \rightarrow X$	$X_0 \div (0.9144) \rightarrow X$
K2-D6	Memory Plus, "M+" MPH → knots	$X_0 \cdot (0.86836) \rightarrow X$	$X_0 \div (0.86836) \rightarrow X$
K2-D7	Memory Recall, "MR" Imp. Gal. → U.S. Gal.	$X_0 \cdot (1.20094) \rightarrow X$	$X_0 \div (1.20094) \rightarrow X$
K2-D8	Clear, "C"	"C"	"C"
K2-D9	N/C	—	—
K3-D1	N/C	—	—
K3-D2	Equal, "=" Acres → Hectares	$X_0 \cdot (0.404687) \rightarrow X$	$X_0 \div (0.404687) \rightarrow X$
K3-D3	Equal Plus, "=+" Cubic Ft → gal	$X_0 \cdot (7.4805) \rightarrow X$	$X_0 \div (7.4805) \rightarrow X$
K3-D4	Change Sign, "CS" Atmospheres → PSI	$X_0 \cdot (14.696) \rightarrow X$	$X_0 \div (14.696) \rightarrow X$
K3-D5	Decimal Point, "." π	$3.1415927 \rightarrow X$	$3.1415927 \rightarrow X$
K3-D6	"9" Oz → cc	$X_0 \cdot (29.5737) \rightarrow X$	$X_0 \div (29.5737) \rightarrow X$
K3-D7	"8" Quarts → liters	$X_0 \cdot (0.946333) \rightarrow X$	$X_0 \div (0.946333) \rightarrow X$
K3-D8	"7" Gal → liters	$X_0 \cdot (3.785332) \rightarrow X$	$X_0 \div (3.785332) \rightarrow X$
K3-D9	"6" Lb → oz	$X_0 \cdot (16) \rightarrow X$	$X_0 \div (16) \rightarrow X$
K4-D1	"5" Oz → grams	$X_0 \cdot (28.3495) \rightarrow X$	$X_0 \div (28.3495) \rightarrow X$
K4-D2	"4" Lb → kilogram	$X_0 \cdot (0.453592) \rightarrow X$	$X_0 \div (0.453592) \rightarrow X$
K4-D3	"3" Stone → lb	$X_0 \cdot (14) \rightarrow X$	$X_0 \div (14) \rightarrow X$
K4-D4	"2" Square Root, " \sqrt{X} "	$\sqrt{X_0} \rightarrow X$	$\sqrt{X_0} \rightarrow X$
K4-D5	"1" Reciprocal, "1/X"	$1/X_0 \rightarrow X$	$1/X_0 \rightarrow X$
K4-D6	"0" °F → °C	$X_0 \cdot (9/5) + 32 \rightarrow X$	$(X_0 - 32) \cdot 5/9 \rightarrow X$
K4-D7	Reverse Shift, "←"	"←"	"←"
K4-D8	Percent, "%" Acre → Sq. ft	$X_0 \cdot (43560) \rightarrow X$	$X_0 \div (43560) \rightarrow X$

EXAMPLES

1. Addition and subtraction of a column of numbers:

		2.0 3.2 <u>-12.3</u>	
KEYS	DISPLAY	COMMENTS	
2	2		
+	2.	2 is entered	
3	3		
.	3.		
2	3.2		
+	5.2	2 + 3.2 is displayed	
1	1		
2	1 2		
.	1 2.		
3	1 2.3		
-	-7.1	12.3 is subtracted from (2 + 3.2)	
C	0.		

2. Repeat add or subtract

KEYS	DISPLAY	COMMENTS
3	3	
.	3.	
1	3.1	
+	3.1	3.1 is entered
+	6.2	3.1 + 3.1 computed
+	9.3	3.1 + 3.1 + 3.1 computed
-	6.2	9.3 - 3.1 computed
C	0.	

3. Chain multiplication or division

KEYS	DISPLAY	COMMENTS
a) Multiplication		
1	1	
x	1.	
2	2	
x	2.	1 x 2 is computed
3.1	3.1	
x	6.2	2 x 3.1 is computed
4.2	4.2	
=	26.0 4	6.2 x 4.2 is computed

b) Division

10	10	
÷	10.	
2	2	
÷	5.	10 ÷ 2 is computed
10	10	
÷	.5	5 ÷ 10 is computed
2	2	
=	.2 5	0.5 ÷ 2 is computed

c) Mixed multiplication and division

20	20	
x	20.	
4	4	
÷	80.	
8	8	
÷	10.	
7	7	
x	1.4 2 8 5 7 1 4	
4	4	
=	5.7 1	Result rounded to two places

4. Constant multiplication or division

KEYS	DISPLAY	COMMENTS
a)		
3	3	
x	3.	
2	2	
=	6.	
4	4	
=	1 2.	First factor in constant multiply
5	5	
.	5.	
2	5.2	
=	1 5.6	
=	4 6.8	
b)		
5	5	
÷	5.	
2	2	
=	2.5	
4	4	
=	2.	Second factor in constant divide
5	5	
.	5.	
2	5.2	
=	2.6	
=	1.3	

5. To perform products of sums

$$(5 + 4) \times (3 + 2) / (6 + 7) =$$

KEYS	DISPLAY	COMMENTS
5	5	
+	5.	
4	4	
+	9.	
x	9.	
3	3	
+	3.	
2	2	
+	5.	
÷	4 5.	(5 + 4) x (3 + 2) is executed
6	6	
+	6.	
7	7	
+	1 3.	
=	3.4 6	45 ÷ (6 + 7) is executed and rounded to two places

6. Calculate percentage

KEYS	DISPLAY	COMMENTS
3	3	
0	3 0	
0	3 0 0	
.	3 0 0.	
2	3 0 0.2	
5	3 0 0.2 5	
x	3 0 0.2 5	
5	5	
%	1 5 0.1	"Live %" key; rounded two places

7. Perform add-on and discount

KEYS	DISPLAY	COMMENTS
a) Add-On		
1	1	
2	1 2	
5	1 2 5.	
x	1 2 5.	
5	5	
%	6.2 5	5% of 125 is displayed
+	1 3 1.2 5	125 + 5% is displayed

EXAMPLES (Continued)

7. (Continued)

KEYS	DISPLAY	COMMENTS
b) Discount		
5	5	
3	5 3	
2	5 3 2	
.	5 3 2.	
1	5 3 2.1	
x	5 3 2.1	
6	6	
%	3 1.9 3	6% of 532.1 is displayed
-	5 0 0.1 7	532.1 - 6% is displayed

8. Perform change sign

KEYS	DISPLAY	COMMENTS
1	1	
2	1 2	
CS	-1 2	Change sign does not terminate entry.
3	-1 2 3	
.	-1 2 3.	
CS	1 2 3.	
5	1 2 3.5	
CS	-1 2 3.5	
6	-1 2 3.5 6	

9. Accumulate in memory, recall and clear memory

KEYS	DISPLAY	COMMENTS
a)		
3	3	
M+	3	Accumulate in memory
4	4	
M+	4	Accumulate in memory
5	5	
MR	7.	Recall memory
MC	7.	Clear memory
MR	0.	
b)		
5	5	
+	5	
6	6	
+	1 1.	
M+	1 1.	Accumulate in memory
7	7	
+	1 8.	
M+	1 8.	Accumulate 11 + 18 in memory
+	2 5.	Repeat add
3	3	
2	3 2	
.	3 2.	
2	3 2 2	
CS	-3 2 2	
M+	-3 2 2	(11 + 18) - 32.2 is accumulated in memory
9	9	
+	3 4.	
MR	-3 2	Accumulated value of M is recalled
+	3 0.8	
MR	-3 2	Accumulated value of M is recalled
MC	-3 2	

10. Accumulate in memory with the "= +" key

KEYS	DISPLAY	COMMENTS
MC	0.	
C	0.	
5	5	
x	5.	
3	3	
= +	1 5.	5 x 3 = 15 is added to M
4	4	
.	4.	
2	4 2	
x	4 2	
3	3.	
= +	1 2.6	4.2 x 3 = 12.6 is added to M

10. (Continued)

KEYS	DISPLAY	COMMENTS
6	6	
÷	6.	
7	7	
= +	.8 6	Rounded to 2 decimal places
9	9	
CS	-9	Note method of multiplying negative number
x	-9.	
4	4	
= +	-3 6.	-9 x 4 = -36 is added to M
MR	-7.5 4	

11. Square root and reciprocal calculations. Find square root of 70064:

KEYS	DISPLAY	COMMENTS
70064	70064	
→	70064.	Either shift key could be used to set up \sqrt{X} function
2 (\sqrt{X})	264.6 9 6 0 5	Square root is computed
←		Either shift key could be used to set up 1/X function
1 (1/X)	.0 0 3 7 7 9 1	Reciprocal is computed

12. Use of constant π : $2\pi r = 2(\pi)(6.8)$

KEYS	DISPLAY	COMMENTS
2	2	
x	2.	
→		Either shift key could be used to set up π
· (π)	3.1 4 1 5 9 2 7	
x	6.2 8 3 1 8 5 4	2π is computed
6.8	6.8	
=	42.7 3	

13. Use of conversion keys:

KEYS	DISPLAY	COMMENTS
2	2	
in → cm	5.08	Two inches is converted to cm
in → cm	12.9 0 3 2	Two square inches is converted to square cm
in → cm	32.7 7 4 1 2 8	Two cubic inches is converted to cubic cm
←	32.7 7 4 1 2 8	Reverse conversion mode is set
in → cm	12.9 0 3 2	
C	0.	
5	5	
→	5.	Data entry is terminated and forward conversion mode is set
7 (gal → liters)	18.9 2 6 6 6	Five gal. is converted to liters
→		
←		Last shift key is valid direction
8 (qts → liters)	20.	Liters → qts computed
12.5	12.5	
KS	12.5	Entry is stored in K
2	2	
→	2.	Forward shift sets up K conversion
KS	25.	Multiply by K
←		
KS	2.	Divide by K
C	0.	
77	77	77°F is entered
→	77.	
0 (°F → °C)	25.	77°F is converted to °C

keyboard outline

/	in/mm	in/cm	in/ft
/	ft/m	yd/m	mi/km
CHS psi/atm	M+ mph/fts	MC	sto K K
=+ ft ³ /gal	MR gal/l gal	% ac / ft ²	= ac / hect
7 gal/lit	8 qt/lit	9 fl.oz/cc	+ +
4 lb/kg	5 oz/gr	6 oz/lb	x x
1 1/x	2 √	3 lb/stn	- -
0 F / C	. π	CE/C	+ +