Complex Standards

MM5738 calculator

general description

The MM5738 calculator was designed with "low system cost" as a major criterion. Through advanced design techniques National Semiconductor has been able to incorporate many desirable features into the MM5738 and still offer significant overall cost effectiveness, probably best emphasized by evaluating the additional components required to fabricate a competitors complete hand-held calculator.

Other than a single DM8864 digit driver, there are *NO* external components necessary to interface the MM5738 to the LED display, keyboard and 9.0V battery of a finished calculator. Figure 1 shows the keyboard matrix and interconnections of these elements.

The MM5738 uses the familiar algebraic notation performing addition, subtraction, multiplication division and percentage operations on positive or negative eight digit, floating point numbers. It is capable of doing chain or constant problems while retaining another number in an independent memory register. The contents of the memory register are only altered upon the depression of the *Memory Store* key and are unaffected by any clear or recall memory operations.

The MM5738 provides an on-chip key debounce circuit that interfaces directly with the appropriate keyboard matrix (Figure 1). While a digit driver is required, the MM5738 can drive the segments of most common cathode LED displays directly. The one-of-nine digit outputs provide the strobe signals necessary to enable the proper digit for display; segment data for each digit appears during the appropriate strobe (Figure 2). The ninth digit is used as a sign or error indicator, and in conjunction with the DM8864 digit driver, as a low voltage indicator. (The decimal point of the ninth digit is usually used as the low voltage indication alerting the user to the need for battery replacement in the near future, without interfering with his normal use of the calculator.) The negative sign always resides one position to the left of the most significant digit of negative numbers and therefore only appears in the ninth position when an eight digit negative number is being displayed.

Leading zero blanking and a display turnoff circuit have been incorporated into the MM5738 to conserve battery life. Battery life is estimated to be between 10 and 15 hours, depending upon battery quality, operating schedule and the average number of digits displayed.

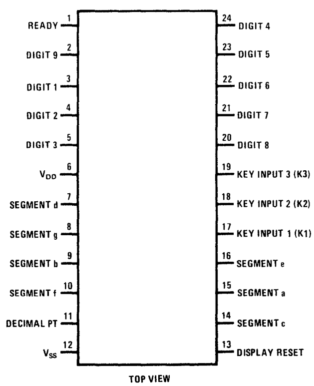
The *READY* pin from the MM5738 is an output signal used to indicate when the calculator is performing an operation. This signal may be helpful if the device is used in a system other than a calculator or for optimizing testing. It is possible to defeat the key debounce circuit for faster key entries.

features

- Full 8-digit capacity
- 5-functions (+, −, x, ÷, %)
- Chain operations
- 2-key memory
- Constant operations independent of memory
- Auto squaring
- Percent discount and tax operations
- Floating decimal point for ease of operation
- Floating negative sign indicator. Tracks most significant digit.
- Convenient algebraic key entry notation
- Leading zero blanking
- On-chip oscillator uses no external components
- Display turnoff (after 16 seconds) with no external components
- Requires only a digit driver to interface with an LED display
- Key debounce uses no external components
- Direct 9.0V battery compatibility

connection diagram

Dual-In-Line Package



Order Number MM5738N
See Package 18

absolute maximum ratings

Voltage at Any Pin Relative to V_{SS} (All other pins connected to V_{SS})	+0.3V to −12.0V
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

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

(V_{SS} always defined as most positive supply voltage)

dc electrical characteristics (Tentative)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Current (I_{DD})	$V_{DD} = V_{SS} - 9.5V$ $T_A = 25°C$			10.5	mA
Keyboard Scan Input Levels (K1 through K3)					
Logical High Level		V_{SS}−2.5			V
Logical Low Level	$V_{DD} = V_{SS} - 6.5V$			V_{SS}−5.0	V
	$V_{DD} = V_{SS} - 9.5V$			V_{SS}−6.0	V
Display Reset Input Levels					
Logical High Level		V_{SS}−1.5			V
Logical Low Level	$V_{DD} = V_{SS} - 6.5V$			V_{SS}−3.5	V
	$V_{DD} = V_{SS} - 9.5V$			V_{SS}−4.5	V
Digit Buffer Output Levels (D1 through D9)					
Logical High Level	$I_{OUT} = -1.2$ mA, $V_{DD} = V_{SS} - 6.5V$	V_{SS}−1.5			V
Logical Low Level	$V_{DD} = V_{SS} - 6.5V$			V_{SS}−6.0	V
	$V_{DD} = V_{SS} - 9.5V$			V_{SS}−7.0	V
Source 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

ac electrical characteristics (Tentative)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Word Time (Figure 2)		0.64		2.4	ms
Digit Time (Figure 2)		70		267	μs
Interdigit Blanking Time (Figure 2)			4.0		μs
Digit Output Transition Times					
Rise	C_{LOAD} = 100 pF		2.0		μs
Fall	C_{LOAD} = 100 pF		5.0		μs
Keyboard Scan Inputs High to Low Transition Time After Key Release	C_{LOAD} = 100 pF		4.0		μs
Key Bounce-out Stability Time (The Time a Keyboard Scan Input Must be Continuously Higher than the Minimum Logical High Level to be Accepted as a Key Closure, or Lower than the Maximum Logical Low Level to be Accepted as a Key Release.)		4.5		17	ms
Display Cutoff Time (The Time After the Last Valid Key Closure at Which the 7 Most-Significant Bits Will be Blanked.)		9.0	16	37	seconds
Calculation Time (Worse Case For: 99999999 ÷ 1 = 99999999.)		0.093		0.35	seconds

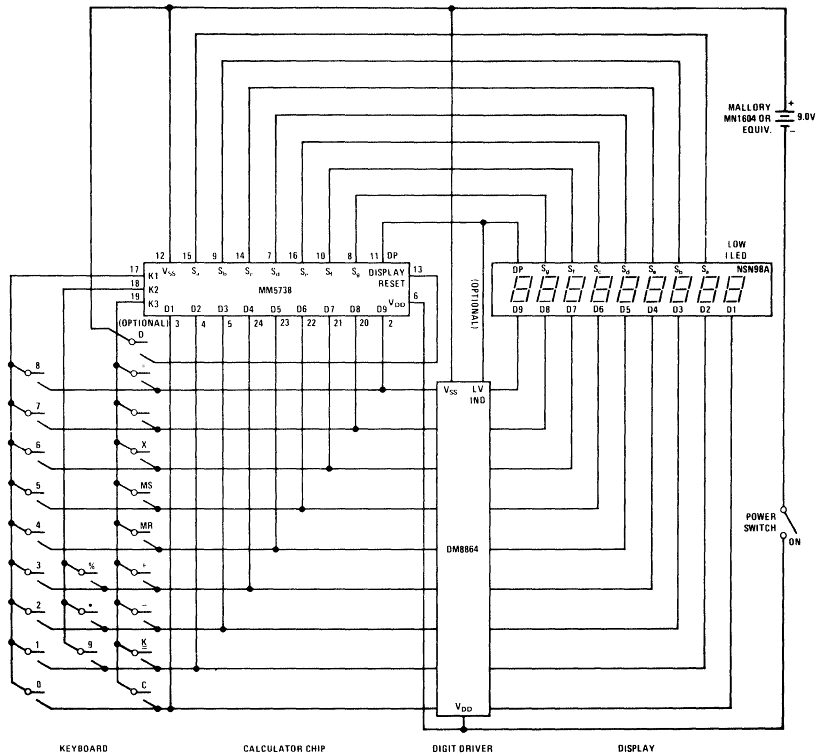


FIGURE 1. MM5738 Calculator with Low Voltage Indicator and Display

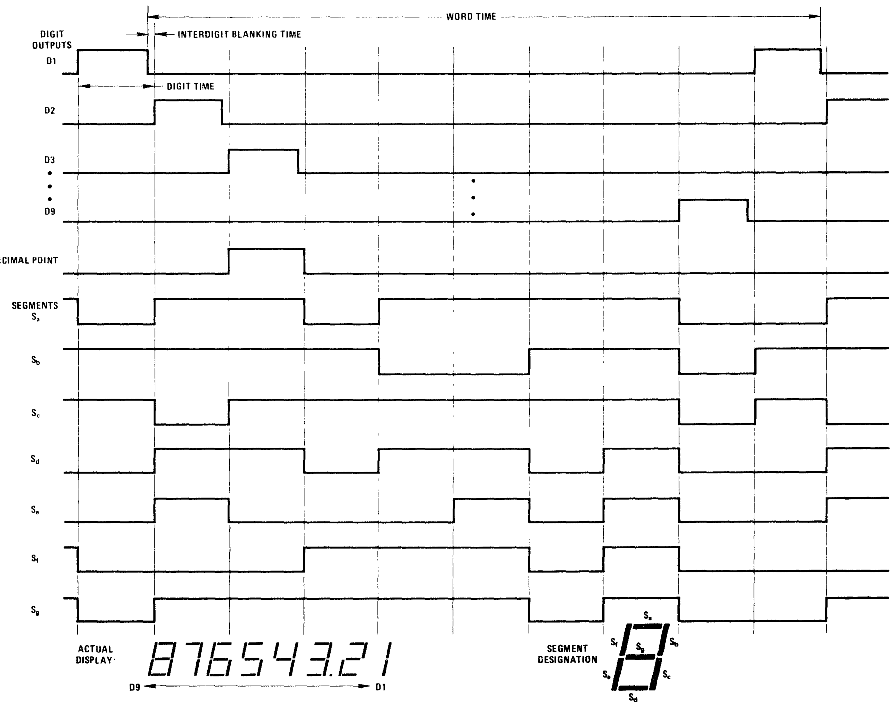


FIGURE 2. Display Timing Diagram

BOUNCE AND NOISE REJECTION

The MM5738 calculator can successfully interface with low cost keyboards. These keyboards are usually the least desirable from a noise and false entry standpoint. When a key closure is sensed by the calculator, an internal timeout is started. Any voltage perturbations of significant magnitude which occur on the *Key Input* Lines (K1, K2 or K3) during the timeout will reset the timer to zero. A key is only accepted as valid after a noise-free timeout period; noise that persists indefinitely will inhibit key entry. Key releases are checked in the same manner.

Low cost conductor loaded elastomeric keyboards often have a key-pressure versus contact resistance characteristic that can generate continuous noise during "teasing" or low pressure key depressions. The MM5738 defines a series switch resistance up to 50 kΩ to be a valid key closure which combined with the resettable debounce timer insures reliable operation under a variety of such conditions.

DISPLAY TURNOFF

The MM5738 has an internal timer which will turn off the seven most significant LEDs when no key closures have been made for a period of sixteen seconds. The previous display will reappear when the *DISPLAY RESET* pin is momentarily connected to V_{SS}. Any other key depressed after a display turnoff reactivates the display, modifying it appropriately. This circuit requires no external components, other than a *DISPLAY RESET* switch (which could be physically part of the keyboard). The option can be disabled by hardwiring the *DISPLAY RESET* pin to V_{SS}.

ERROR CONDITIONS

In the event of an overflow, the MM5738 will display an E and at least the seven most significant digits of the answer, except in the case of division by 0.

An E will also appear if the action of the percent key results in underflow of the decimal point. Once in an error condition, all keys except the *CLEAR* key are ignored. The contents of the memory register are never altered by an error condition or the subsequent clear operation.

KEY OPERATIONS

I. Clear Key

A. Operation during number entry (acts as a clear entry key).

1. First depression clears the entry and displays a previous result.
2. Second depression clears all registers except memory register and displays a zero without decimal point in the least significant digit (LSD).

B. Operation after a function key will clear all registers except the memory register.

C. Operation following Power On: Two depressions are required.

II. Display Key (Momentarily connecting V_{SS} to *DISPLAY RESET* pin.)

A. Depressed before display turn-off will reset the internal timer, and extend the time before turn-off occurs.

B. Depressed after display turn-off will reset the internal timer and return the display without altering the information.

C. Any key depression will also reset the internal timer and activate an updated display.

III. Number Entries

A. First Entry clears the display register and enters the number into the LSD of the register.

B. Second through eighth Entry shifts the display register left one digit and enters the number into the LSD of the register.

C. Subsequent Entries are ignored. Also, only seven positions are allowed to follow the decimal point. Therefore, the eighth number entry after a decimal point would be ignored.

IV. Decimal Point Key

A. First depression of this key will enter a decimal point in the least significant position of the display register. If there have not been previous number entries, the display will show a zero and a decimal point in the LSD.

B. Subsequent depressions of this key before a function key entry will be ignored.

V. Percent Key

Each depression of this key will shift the decimal point two places to the left. If the display has no decimal point, one is inserted in the second position. If shifting results in loss of the decimal point, an E will appear in the ninth LED and the machine will lock out further entries until *CLEAR* is depressed.

A. Depression after a function key will perform the operation described above on the result being displayed and the machine will go to the number entry mode.

B. Depression while in the number entry mode will perform the operation described above.

VI. Memory Store Key

Depression of this key will store the display register information in the memory register. The memory will only retain magnitude information; i.e., it does not store sign data.

VII. Memory Recall Key

Depression of this key will recall the number stored in the memory register and insert it into the display register just as if it had been keyed in as an entry.

VIII. Add Key

A. Depression of this key after an equal key will re-enter the results from the equal operation and record the fact that an addition is the next function to be executed.

B. Depression of this key while in the number entry mode will:

1. Indicate the end of the entry.
2. Perform the previously recorded function, if any.
3. Record the fact that an addition is the next function to be executed.

C. Depression of this key after the subtraction, multiplication, division or an earlier add key, without an interceding number entry, will record the fact that an addition is next function to be executed.

IX. Subtraction Key

Same action as the add key except that subtract will be recorded instead of addition.

X. Multiplication Key

Same action as the add key except that multiplication will be recorded instead of addition.

XI. Division Key

Same action as the add key except that division will be recorded instead of addition.

XII. Equal Key

A. Depression of this key while in the number entry mode will:

1. Indicate the end of the entry.
2. Perform the previously recorded function.
3. Record the fact that an equal key has been depressed.

B. Depression of this key after the add, subtract or divide key, without an interceding number entry, will be ignored.

C. Depression of this key after a multiplication key, without an interceding number entry, will result in an auto squaring of the number being displayed. Subsequent equal key depressions will continue to auto square.

XIII. Constant Key

The number entry following each multiplication or division key is automatically stored in a constant register. (This register is *not* the memory register.)

A. Depression of the constant key while in the multiplication mode will result in multiplying the display by the constant register. The value of the constant remains unchanged.

B. Depression of the constant key while in the division mode will result in dividing the display by the constant register. The value of the constant remains unchanged.

C. Multiple depressions of the constant key is a technique for raising a number to an integer power. The integer may be positive or negative. See the examples.

D. Operation of the constant key in the proper sequence is used for percent discount and tax add on problems. See the examples.

sample problems

I. Addition and Subtraction

A. 23.37 + 243.00 − 489.16 = −222.79

KEY	DISPLAY	COMMENTS
C		
C	0	First C is clear entry.
2	2	
3	2 3	
•	2 3.	
3	2 3.3	
7	2 3.3 7	
+	2 3.3 7	
2 4 3	2 4 3	
−	2 6 6.3 7	Perform addition.
4 8 9.1 7	4 8 9.1 7	Wrong entry.
C	2 6 6.3 7	Clear entry; return previous total.
4 8 9.1 6	4 8 9.1 6	
=	− 2 2 2.7 9	Floating negative indicator.

sample problems (con't)

II. Multiplication

A. 5 x 3.14 = 15.7

KEY	DISPLAY	COMMENTS
C		
C	0	
5	5	
x	5.	
3.1 4	3.1 4	Second entry stored as constant.
=	1 5.7	

B. Continue with a constant operation:

7 x 3.14 = 21.98
.003 x 3.14 = 0.00942

KEY	DISPLAY	COMMENTS
7	7	
K̲	2 1.9 8	K̲ is a dynamic key that is decoded with the others in the keyboard matrix. (Figure 1)
.0 0 3	0.0 0 3	
K̲	0.0 0 9 4 2	

III. Auto Squaring and Raising a Number to a Positive Power (See V for Negative Powers)

A. $5.25^2 = 27.5625$

KEY	DISPLAY	COMMENTS
C		
C	0	
5.2 5	5.2 5	
x	5.2 5	
=	2 7.5 6 2 5	5.25 is stored as a constant.

B. $6.37^3 = 258.47485$,
$6.37^4 = 1646.4847$ and
$6.37^8 = 2710911.8$

KEY	DISPLAY	COMMENTS
C		
C	0	
6.3 7	6.3 7	
X	6.3 7	
=	4 0.5 7 6 9	6.37^2
K̲	2 5 8.4 7 4 8 5	6.37^3
K̲	1 6 4 6.4 8 4 7	6.37^4
=	2 7 1 0 9 1 1.8	= while in X mode always squares the display and also stores a new constant.

IV. Division

A. .4 ÷ .3 = 1.3333333

KEY	DISPLAY	COMMENTS
C		
C	0	
.4	0.4	
÷	0.4	Second entry stored as constant.
.3	0.3	
=	1.3 3 3 3 3 3 3	

sample problems (con't)

B. Continue, with constant calculations:

.0005 ÷ .3 = 0.0016666
3 ÷ .3 = 10.

KEY	DISPLAY	COMMENTS
.0 0 0 5	0.0 0 0 5	
K̲=	0.0 0 0 1 6 6 6 6	
3	3	
K̲=	1 0.	

V. Raising a Number to a Negative Power

A. 4.3176^{-3} = 0.0124243

KEY	DISPLAY	COMMENTS
C		
C	0	
1	1	
÷	1	
4.3 1 7 6	4.3 1 7 6	Constant is stored.
=	0.2 3 1 6 1 0 1	
K̲=	0.0 5 3 6 4 3 2	
K̲=	0.0 1 2 4 2 4 3	

B. $.7356^{-5}$ = 4.6429217

KEY	DISPLAY	COMMENTS
C		
C	0	
1	1	
÷	1	
.7 3 5 6	0.7 3 5 6	
=	1.3 5 9 4 3 4	
K̲=	1.8 4 8 0 6 1	
K̲=	2.5 1 2 3 1 7	
K̲=	3.4 1 5 3 3	
K̲=	4.6 4 2 9 1 7	

C. $.7356^{-9}$ = 15.85708 using auto square and memory

KEY	DISPLAY	COMMENTS
C		
C	0	
1	1	
÷	1	
.7 3 5 6	0.7 3 5 6	
S	0.7 3 5 6	Store to memory.
=	1.3 5 9 4 3 4	$.7356^{-1}$
X	1.3 5 9 4 3 4	Re-enter results.
=	1.8 4 8 0 6 0 8	$.7356^{-2}$
=	3.4 1 5 3 2 8 7	$.7356^{-4}$
=	1 1.6 6 4 4 7	$.7356^{-8}$
÷	1 1.6 6 4 4 7	Re-enter results.
R	0.7 3 5 6	Recall memory.
=	1 5.8 5 7 0 8	$.7356^{-9}$

sample problems (con't)

VI. Chain Operations Using Memory and %

$$\frac{-(131/19.6) + (0.045 - 26.31) \times 1001.2}{37.65} \times 87\% = 607.8030$$

KEY	DISPLAY	COMMENTS
C		
C	0	
1 3 1	1 3 1	
÷	1 3 1	
1 9.6	1 9.6	
=	6.6 8 3 6 7 3	
S	6.6 8 3 6 7 3	Store to memory.
.0 4 5	0.0 4 5	
−	0.0 4 5	
2 6.3 1	2 6.3 1	
X	−2 6.2 6 5	
1 0 0 1.2	1 0 0 1.2	
−	−2 6 2 9 6.5 1 8	
R	6.6 8 3 6 7 3	Recall from memory.
÷	−2 6 3 0 3.2 0 1	
3 7.6 5	3 7.6 5	
X	−6 9 8.6 2 4 1	
8 7	8 7	
%	0.8 7	% can be used with +, −, x, or ÷.
=	−6 0 7.8 0 2 9 6	

VII. Evaluating an Expense Account Using Memory

	Mon	Tues	Wed	Thurs	Fri	Total
Breakfast		1.25	1.37	1.75	1.37	5.74
Lunch	2.65	1.97	2.35	3.15	2.98	13.10
Dinner	7.50	6.85	8.32	7.25		29.92
Lodging	21.50	21.50	21.50	21.50		86.00
Telephone	1.75	.75	.00	1.97		4.47
Transportation	3.75		3.25		3.75	10.75
Totals	37.15	32.32	36.79	35.62	8.10	149.98

KEY	DISPLAY	COMMENTS
C		
C	0	Find weekly totals:
1.2 5	1.2 5	
+	1.2 5	
1.3 7	1.3 7	
+	2.6 2	
1.7 5	1.7 5	
+	4.3 7	
1.3 7	1.3 7	
=	5.7 4	Breakfast total.
S	5.7 4	Store to memory.
2.6 5	2.6 5	
+	2.6 5	
1.9 7	1.9 7	
+	4.6 2	
2.3 5	2.3 5	
+	6.9 7	
3.1 5	3.1 5	
+	1 0.1 2	
2.9 8	2.9 8	

sample problems (con't)

VII. Continued

KEY	DISPLAY	COMMENTS
+	1 3.1	Lunch total.
R	5.7 4	
=	1 8.8 4	Calculate and store.
S	1 8.8 4	New subtotal.
7.5 0	7.5	
+	7.5	
6.8 5	6.8 5	
+	1 4.3 5	
8.3 2	8.3 2	
+	2 2.6 7	
7.2 5	7.2 5	
+	2 9.9 2	Dinner total.
R	1 8.8 4	
=	4 8.7 6	Calculate and store.
S	4 8.7 6	New subtotal.
2 1.5 0	2 1.5 0	
X	2 1.5 0	
4	4	
+	8 6.	Lodging total.
R	4 8.7 6	
=	1 3 4.7 6	Calculate and store.
S	1 3 4.7 6	New subtotal.
1.7 5	1.7 5	
+	1.7 5	
0.7 5	0.7 5	
+	2.5	
1.9 7	1.9 7	
+	4.4 7	Phone total.
R	1 3 4.7 6	
=	1 3 9.2 3	Calculate and store.
S	1 3 9.2 3	New subtotal.
3.7 5	3.7 5	
+	3.7 5	
3.2 5	3.2 5	
+	7.	
3.7 5	3.7 5	
+	1 0.7 5	Cab total.
R	1 3 9.2 3	
=	1 4 9.9 8	Calculate total.

The same technique is used to find the daily subtotals and the double-check of the accumulative total.

VIII. Evaluate a Polynomial Using Constant and Memory

Find: $3x^3 + 2x^2 + 3.1x - 16 = ?$, for $x = 5.1$

KEY	DISPLAY	COMMENTS
C		
C	0	
3	3	
X	3	
5.1	5.1	
=	1 5.3	
K	7 8.0 3	
K	3 9 7.9 5 3	Calculate $3x^3$
S	3 9 7.9 5 3	Store $3x^3$
2	2	

sample problems (con't)

VIII. Continued

KEY	DISPLAY	COMMENTS
K	10.2	
K	52.02	Calculate $2x^2$
+	52.02	Re-enter $2x^2$
R	397.953	Recall $3x^3$
=	449.973	Calculate $3x^3 + 2x^2$
S	449.973	Store $3x^3 + 2x^2$
3.1	3.1	
X	3.1	
K	15.81	Calculate 3.1x
+	15.81	Re-enter 3.1x
R	449.973	Recall $3x^3 + 2x^2$
−	465.783	Calculate $3x^3 + 2x^2 + 3.1x$
16	16	
=	449.783	Calculate $3x^3 + 2x^2 + 3.1x - 16$

IX. Evaluate a Polynomial after Factoring. (Note the Convenience of Algebraic Notation.)

Find: $23.4x^3 - 5.3x^2 + .6x - 178 = ?$, for x = 2.7

Factoring: $[(23.4x - 5.3)x + .6]\,x - 178 = ?$

KEY	DISPLAY	COMMENTS
C		
C	0	
23.4	23.4	
X	23.4	
2.76	2.76	Store X to memory for further use and to save key entry.
S	2.76	
−	64.584	
5.3	5.3	
X	59.284	
R	2.76	
+	163.62384	
.6	0.6	
X	164.22384	
R	2.76	
−	453.25779	
178	178	
=	275.25779	

X. Adding and Subtracting Percentages

3.5% + 2.7% − 12.6% + 3.1% = −0.033

KEY	DISPLAY	COMMENTS
C		
C	0	
3.5	3.5	
%	0.035	% key moves decimal point 2 positions to left.
+	0.035	
2.7	2.7	
%	0.027	
−	0.062	
12.6	12.6	
%	0.126	
+	−0.064	
3.1	3.1	
%	0.031	
=	−0.033	

sample problems (con't)

XI. Multiplication and Division Using % Key

A. Find the 5.5% tax on the following items: $135.63, $127.35, $189.79.

KEY	DISPLAY	COMMENTS
C		
C	0	
135.63	135.63	
X	135.63	
5.5	5.5	5.5% is stored as constant.
%	0.055	
=	7.45965	5.5% of $135.63 is $7.46.
127.35	127.35	
K=	7.00425	5.5% of $127.35 is $7.80.
189.79	189.79	
K=	10.43845	5.5% of $189.79 is $10.44.

B. Mark-up Problem

Find the retail price of the following items if they are to be marked-up 33% over these wholesale prices: $89.50, $127.29, $149.95.

KEY	DISPLAY	COMMENTS
C		
C	0	
89.50	89.50	
÷	89.50	
77	77	Items are at 77% of retail.
%	0.77	
=	116.23376	
127.29	127.29	
K=	165.3116	
149.95	149.95	
K=	194.7402	

C. Find 5% tax on a $129.99 item and then add it on to find total cost to customer.

KEY	DISPLAY	COMMENTS
C		
C	0	
5	5	On this type of problem the percentage must be entered first.
%	0.05	
X	0.05	
129.99	129.99	
+	6.4995	Tax is calculated, then added on.
K=	136.4895	Total cost is calculated.

D. A salesman, whose commission on a $975.37 sale is 18%, wants to know what his profit is and how much to send to the company.

KEY	DISPLAY	COMMENTS
C		
C	0	
18	18	
%	0.18	On this type of problem the percentage must be entered first.
X	0.18	
975.37	975.37	
−	175.5666	Profit is calculated then discounted.
K=	799.8034	Difference is calculated

sample problems (con't)

XII. Problem Using % and Memory

A color TV which is normally priced at $599.99 is marked down 20%. When purchased, the following figures are required:

1. Amount of savings to customer.
2. Sales price
3. 6% sales tax
4. Total amount of transaction

KEY	DISPLAY	COMMENTS
C		
C	0	
2 0	2 0	
%	0.2 0	Enter percentage first.
X	0.2 0	
5 9 9.9 9	5 9 9.9 9	
−	1 1 9.9 9 8	Savings to customer.
K =	4 7 9.9 9 2	Sales price.
S	4 7 9.9 9 2	Store sales price.
6	6	
%	0.0 6	Enter percentage first.
X	0.0 6	
R	4 7 9.9 9 2	Recall sales price.
+	2 8.7 9 9 5 2	Tax due.
K =	5 0 8.7 9 1 5 2	Amount of transaction.