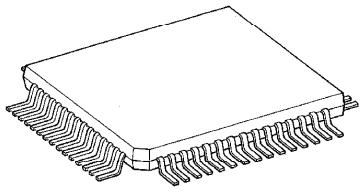
TOSHIBA CMOS DIGITAL INTEGRATED CIRCUIT SILICON MONOLITHIC

T7987A, JT7987AY-CS

T7987A, JT7987AY-CS SINGLE-CHIP CMOS LSI FOR LCD CALCULATORS

The T7987A, JT7987AY-CS is single-chip microcomputer for 10-digit + 2-digit scientific calculation.
T7987A, JT7987AY-CS is the complete single-chip CMOS LSI for calculator with 10 digits, 67 functions, 3 expression and hexadecimal, octal and binary, statistic calculation, fractional number calculation, and logic operation with the following features.



LQFP60-P-1414-0.80

Weight : 0.66g (Typ.)

FEATURES

- 12-digit display plus 2 digits code at the right margin.
  - Scientific and engineering display.

    Mantissa 10 digits plus exponent 2 digits plus negative code 2 digits.
  - Other than above

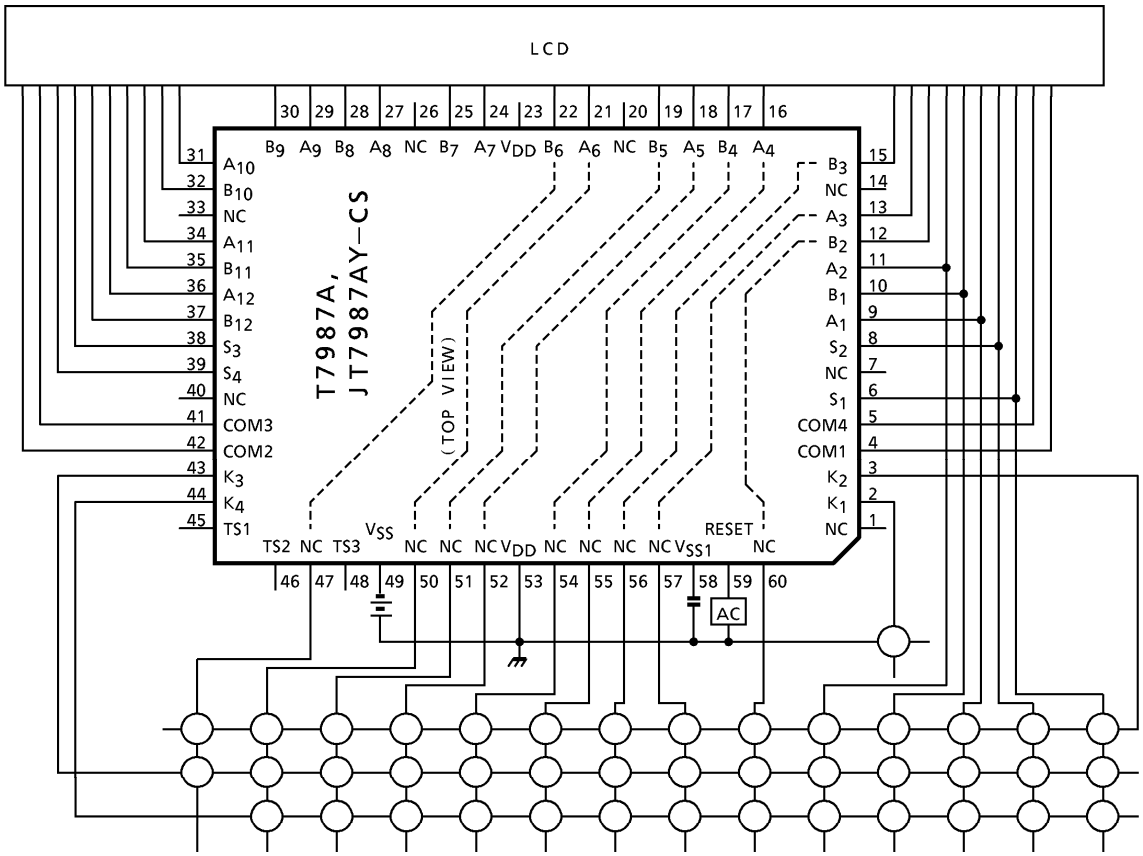
    Mantissa 10 digits plus negative code 1 digit.
- 13 kinds of special display

M	Memory	HEX	Hexadecimal mode
–	Mantissa and exponent Minus	SD	Statistic calculation mode
E	Error	DEG	Degree
INV	Inverse	RAD	Radian
HYP	Hyperbolic	GRAD	Gradian
BIN	Binary mode	( )	Parenthesis calculation
OCT	Octal mode		

- The minus sign of the mantissa is floating minus.
- The arithmetic key operation in clouding Y^X or $\sqrt[X]{Y}$ has same sequence as mathematical equation. 6 pending operations are allowed and ( ) are up to continuous 15 levels.
- Fractional number calculation.
- Statistic calculation includes 3 kinds of the normal distribution, total 9 kinds.
- It is possible to convert mutually between decimal, binary, octal and hexadecimal, and the four operations in arithmetic in binary, octal and hexadecimal.
- One independent accumulating memory.

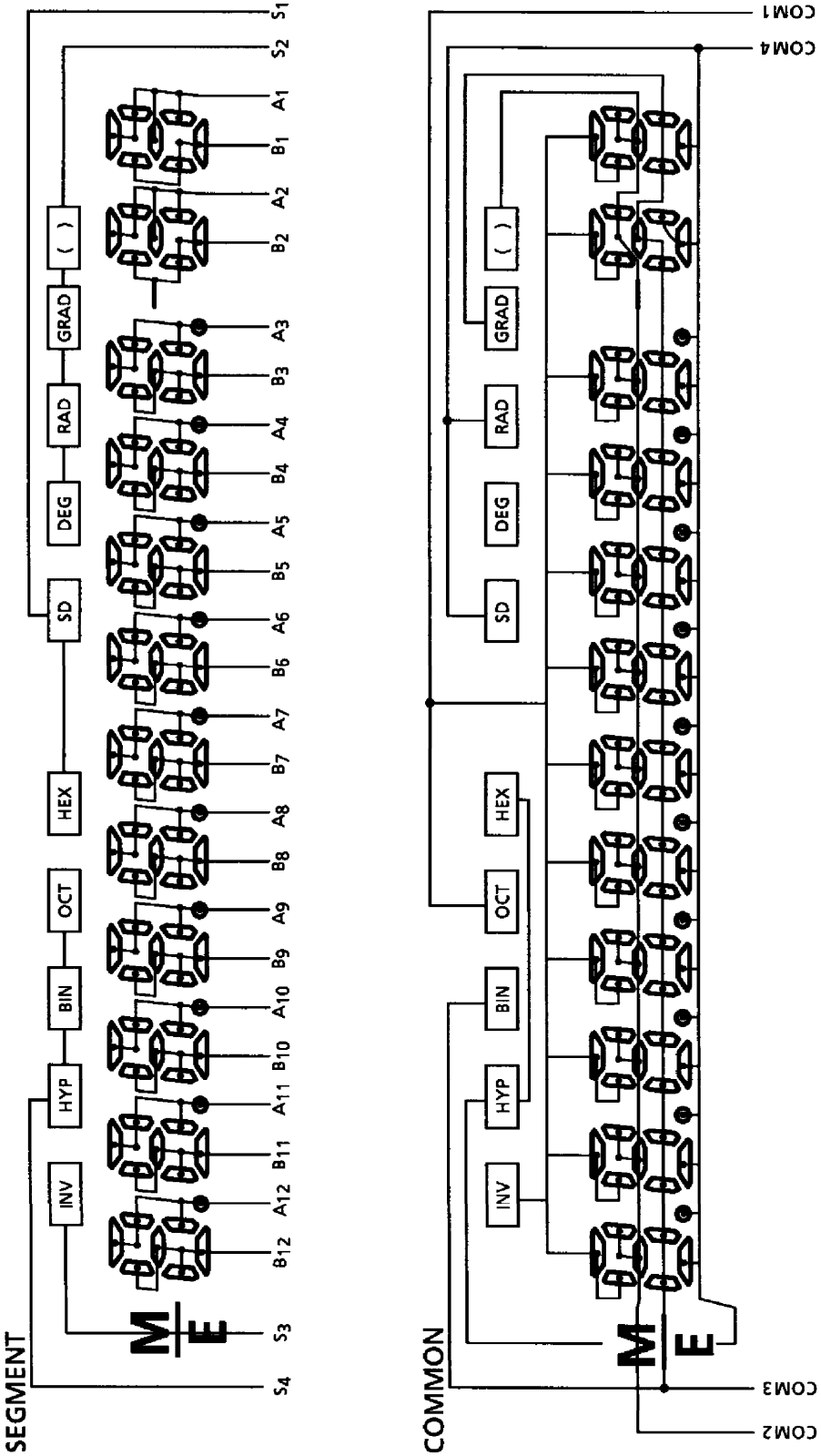
- It is possible to convert or fix the display number system by FLO (Floating) , SCI (Scientific) or ENG (Engineering) key.
- It is possible to specify decimal part digits (0~9) by FIX key.
- Direct drive for FEM LCD (1 / 3 prebias, 1 / 4 duty) .
- Automatic power on clear.
- Low-power consumption. V_{SS} = – 3.0V single power supply.
- The 60-pin flat package is used.

SYSTEM BLOCK DIAGRAM



(Note) Input capacity ≦ 400 (pF) at V_{SS} = – 3.0 (V)
Key resistance ≦ 3.0 (kΩ) at V_{SS} = – 3.0 (V)

CONNECTION OF LCD



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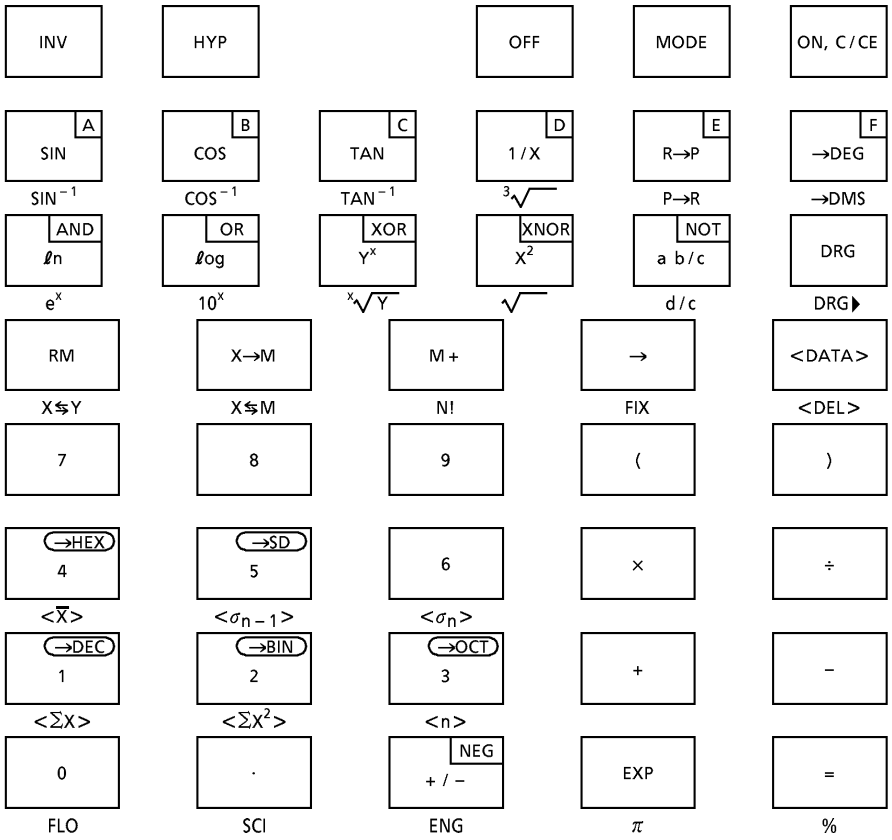
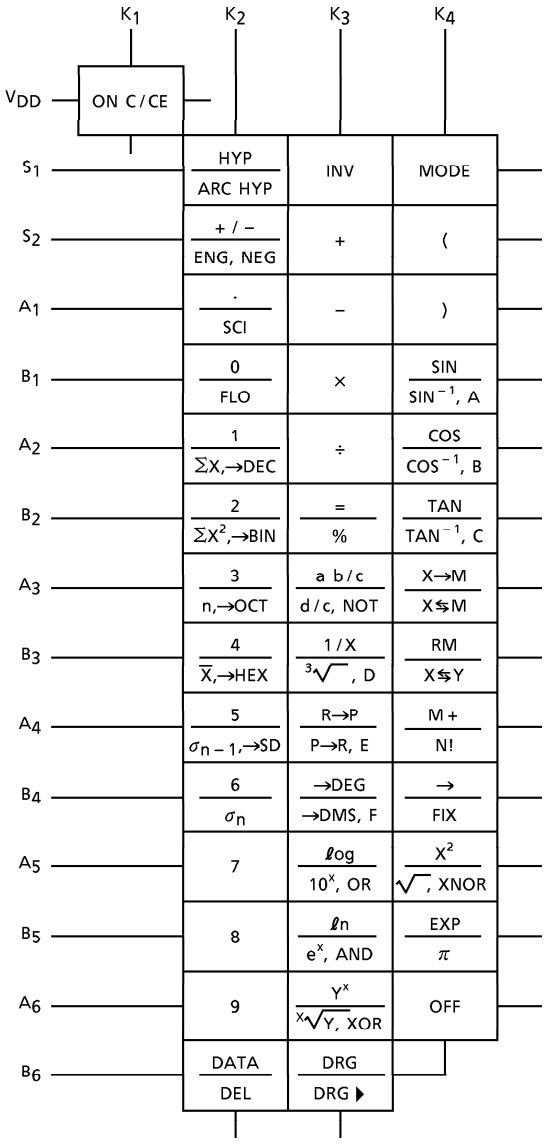
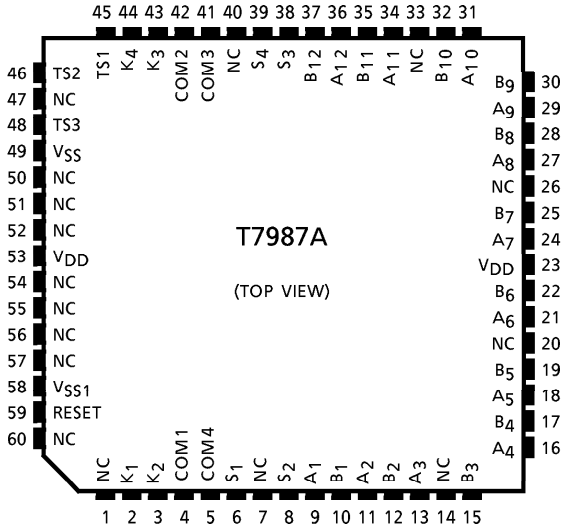
SET KEY LAYOUT (Example)



KEY CONNECTION



PIN ASSIGNMENT



SPECIFICATION OF CALCULATOR

Speed of calculation

Key on 4.8ms Key off 34.4ms $f\phi WAIT = 15kHz$, $f\phi op = 80kHz$

The calculation speed doesn't include the key on or off time.

ITEM	OPERATION			CALCULATION SPEED (ms)
Number	DEC		5	8
		5	5	8
	HEX		A	9
		A	A	9
Function	DEC	5	+	20
		5	×	21
	HEX	A	−	51
		A	÷	52
4 operation	DEC	1 + 2	+	29
		1 0 0 0 0 0 0 0 0 0 − 1	−	31
		5 × 9	×	31
		5 5 5 5 5 × 9 9 9 9 9	×	36
		5 ÷ 9	÷	47
		5 5 5 5 5 ÷ 9 9 9 9 9	÷	58
	HEX	A B C + D E F	+	88
		A B C − D E F	−	144
		A B C × D E F	×	100
		A B C ÷ D E F	÷	98
Y^X, $\sqrt[X]{Y}$	3 Y^X 4		=	252
	3 $\sqrt[X]{Y}$ 4		=	262

ITEM	OPERATION			CALCULATION SPEED (ms)
SIN	DEG	3 0	SIN	241
	RAD	π ÷ 6 =	SIN	231
	GRAD	1 0 0 ÷ 3 =	SIN	350
COS	DEG	6 0	COS	244
	RAD	π ÷ 3 =	COS	311
	GRAD	2 0 0 ÷ 3 =	COS	354
TAN	DEG	4 5	TAN	118
	RAD	π ÷ 4 =	TAN	45
	GRAD	5 0	TAN	48
SIN^{-1}	DEG	0 . 5	SIN^{-1}	252
	RAD	0 . 5	SIN^{-1}	198
	GRAD	0 . 5	SIN^{-1}	249
COS^{-1}	DEG	0 . 5	COS^{-1}	322
	RAD	0 . 5	COS^{-1}	230
	GRAD	0 . 5	COS^{-1}	319
TAN^{-1}	DEG	1	TAN^{-1}	73
	RAD	1	TAN^{-1}	46
	GRAD	1	TAN^{-1}	72
Ln		2 0	ln	47
Log		2 0	ℓog	99
e^x		2 0	e^x	94
10^x		1 . 2 3	10^x	113
		1 0	10^x	40
X!		6 9	N!	291
HYP		3 hyp	SIN	189
		3 hyp	COS	190
		3 hyp	TAN	232
ARC HYP		3 hyp^{-1}	SIN	184
		3 hyp^{-1}	COS	205
		0.5 hyp^{-1}	TAN	174
X^2		2 0	X^2	18
$\sqrt{}$		2 0	$\sqrt{}$	64
1 / X		2 0	1 / X	23
$\sqrt[3]{}$		2 0	$\sqrt[3]{}$	180
Mutual Conversion	DEC	1 2 3	→BIN	35
		1 2 3 4 5	→OCT	40
		1 2 3 4 5	→HEX	35
	BIN	1 0 1 0 1	→DEC	27
	OCT	1 2 3 4 5	→DEC	33
	HEX	A B C D E	→DEC	54
→DEG		1.2 3 4 5	→DEG	78
→DMS		1.2 3 4 5	→DMS	87

ITEM	OPERATION			CALCULATION SPEED (ms)
R→P	DEG	$\sqrt[3]{\ }$ X⇆Y 1	R→P	275
	RAD	$\sqrt[3]{\ }$ X⇆Y 1	R→P	216
	GRAD	$\sqrt[3]{\ }$ X⇆Y 1	R→P	274
P→R	DEG	2 X⇆Y 3 0	P→R	462
	RAD	2 X⇆Y 30 DRG▸	P→R	437
	GRAD	2 X⇆Y 30 DRG▸ DRG▸	P→R	626
→RAD	DEG	3 6 0	DRG▸	43
→GRAD	RAD	2 × π =	DRG▸	29
→DEG	GRAD	4 0 0	DRG▸	20
Memory		1 2 3	X→M	17
		1 2 3 X→M	M+	19
		1 2 3 X→M	RM	12
		1 2 3 X→M	X⇆M	19
%		1 2 3 + 4 5 6	%	26
		1 2 3 − 4 5 6	%	26
		1 2 3 × 4 5 6	%	17
		1 2 3 ÷ 4 5 6	%	17
Exchange		1 2 3 + 4 5 6	X⇆Y	15
Shift		1 2 3	→	8
Statistic Calculation	1 DATA 2 DATA 3 DATA …… 8 DATA 9		DATA	38
	The above-mentioned data		n	16
			$\overline{X}$	21
			ΣX	15
			ΣX^2	15
			σ_{n-1}	90
			σ_n	104
Logic operation	HEX	A B C AND D E F	=	181
		A B C OR D E F	=	195
		A B C XOR D E F	=	171
		A B C XNOR D E F	=	289
		A B C	NOT	118
NEG	HEX	A B C	NEG	112
Fractional number calculation	Function	2 ab/c 3 6 ab/c 2 3 4	−	75
		2 ab/c 3 6 ab/c 2 3 4	÷	76
	4-operation	2 _ 36⌟ 234 + 3 _ 45 ⌟ 345	=	161
		2 _ 36⌟ 234 − 3 _ 45 ⌟ 345	=	153
		2 _ 36⌟ 234 × 3 _ 45 ⌟ 345	=	149
		2 _ 36⌟ 234 ÷ 3 _ 45 ⌟ 345	=	168

OPERATION RANGE AND ACCURACY

FUNCTION	ANGLE UNIT	OPERATION RANGE	UNDER FLOW AREA	NORMAL ACCURACY
SIN X	DEG	$0 \leqq \|X\| \leqq 4.499999999 \times 10^{10}$	$0 \leqq \|X\| \leqq 5.729577951 \times 10^{-98}$	±1 in 10th significant digit
	RAD	$0 \leqq \|X\| \leqq 785398163.3$	—	
	GRAD	$0 \leqq \|X\| \leqq 4.999999999 \times 10^{10}$	$0 \leqq \|X\| \leqq 6.366197723 \times 10^{-98}$	
COS X	DEG	$0 \leqq \|X\| \leqq 4.500000008 \times 10^{10}$	—	
	RAD	$0 \leqq \|X\| \leqq 785398164.9$	—	
	GRAD	$0 \leqq \|X\| \leqq 5.000000009 \times 10^{10}$	—	
TAN X	DEG	SAME AS SIN X except for $\|X\| = (2n-1) \cdot 90$	SAME AS SIN X	
	RAD	SAME AS SIN X except for $\|X\| = (2n-1) \cdot \pi / 2$	SAME AS SIN X	
	GRAD	SAME AS SIN X except for $\|X\| = (2n-1) \cdot 100$	SAME AS SIN X	
$SIN^{-1}X$	DEG	$0 \leqq \|X\| \leqq 1$	$0 \leqq \|X\| \leqq 1.570796326 \times 10^{-99}$	
	RAD	$0 \leqq \|X\| \leqq 1$	—	
	GRAD	$0 \leqq \|X\| \leqq 1$	$0 \leqq \|X\| \leqq 1.570796326 \times 10^{-99}$	
$COS^{-1}X$	DEG	SAME AS $SIN^{-1}X$	—	
	RAD	SAME AS $SIN^{-1}X$	—	
	GRAD	SAME AS $SIN^{-1}X$	—	
$TAN^{-1}X$	DEG	$0 \leqq \|X\| \leqq 9.999999999 \times 10^{99}$	SAME AS $SIN^{-1}X$	
	RAD	$0 \leqq \|X\| \leqq 9.999999999 \times 10^{99}$	—	
	GRAD	$0 \leqq \|X\| \leqq 9.999999999 \times 10^{99}$	SAME AS $SIN^{-1}X$	
LN X		$0 < X$	—	
LOG X		$0 < X$	—	
e^X		$-9.999999999 \times 10^{99} \leqq X \leqq 230.2585092$	$-9.999999999 \times 10^{99} \leqq X \leqq -227.9559243$	
10^X		$-9.999999999 \times 10^{99} \leqq X \leqq 99.99999999$	$-9.999999999 \times 10^{99} \leqq X \leqq -99.00000001$	
X!		$0 \leqq X \leqq 69$ (INTEGER)	—	
$\frac{1}{X}$		$1 \times 10^{-99} \leqq \|X\| \leqq 9.999999999 \times 10^{99}$	$1.000000001 \times 10^{99} \leqq \|X\| \leqq 9.999999999 \times 10^{99}$	
X^2		$0 \leqq \|X\| \leqq 9.999999999 \times 10^{49}$	$0 \leqq \|X\| \leqq 3.162277660 \times 10^{-50}$	
$\sqrt{X}$		$0 \leqq X \leqq 9.999999999 \times 10^{99}$	—	
$\sqrt[3]{X}$		$0 \leqq \|X\| \leqq 9.999999999 \times 10^{99}$	—	
DMS→DEG		$0 \leqq \|X\| \leqq 9.999999999 \times 10^{9}$	—	
DEG→DMS		$0 \leqq \|X\| \leqq 9999999.999$	$0 \leqq \|X\| \leqq 1.388888888 \times 10^{-6}$	±1 in least significant digit

FUNCTION	OPERATION RANGE	UNDER FLOW AREA	NORMAL ACCURACY
SINH X	$0 \leqq \|X\| \leqq 230.2585092$	—	±1 in 10th significant digit
COSH X	$0 \leqq \|X\| \leqq 230.2585092$	—	
TANH X	$0 \leqq \|X\| \leqq 9.999999999 \times 10^{99}$	—	
$SINH^{-1}X$	$0 \leqq \|X\| \leqq 4.999999999 \times 10^{99}$	—	
$COSH^{-1}X$	$1 \leqq X \leqq 4.999999999 \times 10^{99}$	—	
$TANH^{-1}X$	$0 \leqq \|X\| \leqq 9.999999999 \times 10^{-1}$	—	
R→P ($xy \rightarrow \gamma\theta$)	$\|x\|, \|y\| \leqq 9.999999999 \times 10^{49}$ $(x^2 + y^2) \leqq 9.999999999 \times 10^{99}$ $\frac{Y}{X}$; SAME AS $TAN^{-1}X$	$\frac{Y}{X}$; SAME AS $TAN^{-1}X$	
P→R ($\gamma\theta \rightarrow xy$)	$0 \leqq \gamma \leqq 9.999999999 \times 10^{99}$ θ ; SAME AS SIN X, COS X	θ ; SAME AS SIN X, COS X	
DEG→RAD	$0 \leqq \|X\| \leqq 9.999999999 \times 10^{99}$	$0 \leqq \|X\| \leqq 5.729577951 \times 10^{-98}$	
RAD→GRAD	$0 \leqq \|X\| \leqq 1.570796326 \times 10^{98}$	—	
GRAD→DEG	$0 \leqq \|X\| \leqq 9.999999999 \times 10^{99}$	$0 \leqq \|X\| \leqq 1.111111111 \times 10^{-99}$	
Y^X	$-9.999999999 \times 10^{99}$ $\leqq X \cdot LN \|Y\| \leqq 230.2585092$	$-9.999999999 \times 10^{99}$ $\leqq X \cdot LN \|Y\| \leqq -227.9559243$	±1 in 10th significant digit
	(1) $Y > 0$ ··· The above-mentioned operation range. (2) $Y < 0$ ··· X (Integer) or, 1 / X (Odd, $X \neq 0$) ··· The above-mentioned operation range. (3) $Y = 0 \cdots 0 < X$		
$\sqrt[X]{Y}$	$-9.999999999 \times 10^{99}$ $\leqq \frac{1}{X} \cdot LN \|Y\| \leqq 230.2585092$	$-9.999999999 \times 10^{99}$ $\leqq \frac{1}{X} \cdot LN \|Y\| \leqq -227.95593243$	±1 in 10th significant digit
	(1) $Y > 0$ ··· The above-mentioned operation range. (2) $Y < 0$ ··· X (Odd) or 1 / X (Integer, $X \neq 0$) ··· The above-mentioned operation range. (3) $Y = 0 \cdots 0 < X$		
→DEC	Operation range The following operation range after the conversion. $0 \leqq \|X\| \leqq 9999999999$		—
→BIN	The following operation range after the conversion. $1000000000 \leqq X \leqq 1111111111$ $0 \leqq X \leqq 111111111$		—
→OCT	The following operation range after the conversion. $4000000000 \leqq X \leqq 7777777777$ $0 \leqq X \leqq 3777777777$		—
→HEX	The following operation range after the conversion. $FDABF41CO1 \leqq X \leqq FFFFFFFFFF$ $0 \leqq X \leqq 2540BE3FF$		—

FUNCTION		OPERATION RANGE	NORMAL ACCURACY
AND OR XOR XNOR		BIN ; $1000000000 \leqq X \leqq 1111111111$ $0 \leqq X \leqq 111111111$ OCT ; $4000000000 \leqq X \leqq 7777777777$ $0 \leqq X \leqq 3777777777$ HEX ; The following operation range after the operation. $FDABF41CO1 \leqq X \leqq FFFFFFFFFF$ $0 \leqq X \leqq 2540BE3FF$	—
NOT		BIN ; SAME AS AND OCT ; SAME AS AND HEX ; $FDABF41CO1 \leqq X \leqq FFFFFFFFFF$ $0 \leqq X \leqq 2540BE3FE$	—
NEG		BIN ; $1000000001 \leqq X \leqq 1111111111$ $0 \leqq X \leqq 111111111$ OCT ; $4000000001 \leqq X \leqq 7777777777$ $0 \leqq X \leqq 3777777777$ HEX ; $FDABF41CO1 \leqq X \leqq FFFFFFFFFF$ $0 \leqq X \leqq 2540BE3FF$	—
Statistic	DATA DEL	$\lvert x \rvert \leqq 9.999999999 \times 10^{49}$ $\lvert \Sigma x \rvert \leqq 9.999999999 \times 10^{99}$ $\Sigma x^2 \leqq 9.999999999 \times 10^{99}$ $0 \leqq n \leqq 9999999999$. n = Integer	±1 in 10th significant digit
	$\bar{x}$	$n \neq 0$	
	$\sigma n-1$	$n \neq 1,\ n \neq 0$ $0 \leqq \frac{\Sigma X^2 - \{(\Sigma X)^2 / n\}}{n-1} \leqq 9.999999999 \times 10^{99}$	
	σn	$n \neq 0$ $0 \leqq \frac{\Sigma X^2 - \{(\Sigma X)^2 / n\}}{n} \leqq 9.999999999 \times 10^{99}$	

MAXIMUM RATINGS (Ta = 25°C)

CHARACTERISTICS	SYMBOL	RATING	UNIT
Supply Voltage	V_{SS}	+0.3~−3.5	V
Input Voltage	V_{IN}	+0.3~V_{SS}−0.3	V
Operating Temperature	T_{opr}	0~40	°C
Storage Temperature	T_{stg}	−55~125	°C

ELECTRICAL CHARACTERISTICS (V_{SS} = −3.0 ± 0.2V, V_{DD} = 0V, Ta = 25 ± 1.5°C)

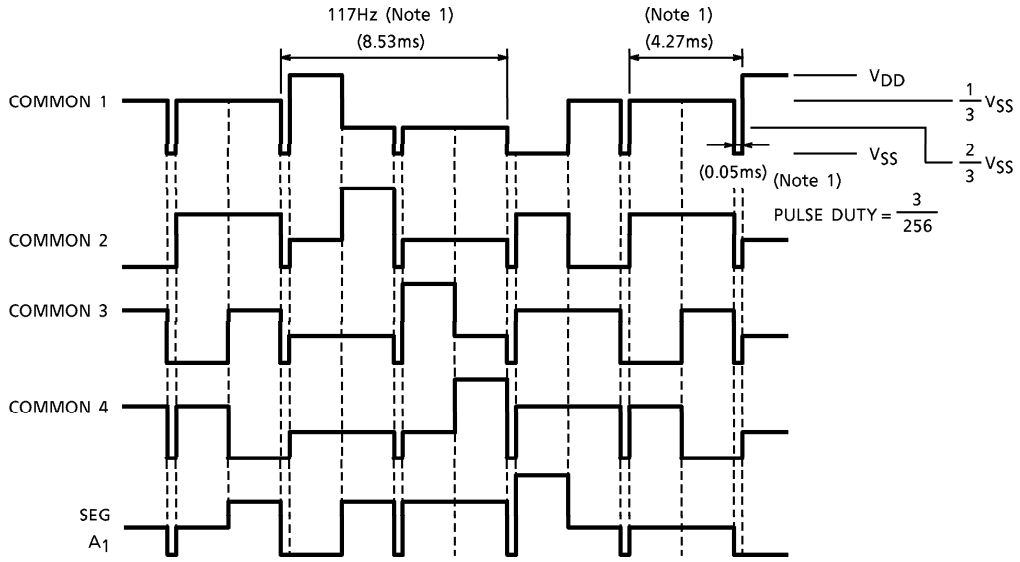
CHARACTERISTICS	SYMBOL	TEST CIR-CUIT	PIN NAME	TEST CONDITION	MIN	TYP.	MAX	UNIT
Operating Voltage	—	—	—	—	−2.5	−3.0	−3.4	V
Supply Current	I_{DD} WAIT	—	—	V_{SS} = −3.0V, wait	—	20	35	μA
Supply Current	I_{DD} OP	—	—	V_{SS} = −3.0V, operate	—	70	120	μA
Supply Current	I_{DD} OFF	—	—	V_{SS} = −3.0V, off	—	1	3	μA
Oscillating Frequency	Fϕ WAIT	—	—	V_{SS} = −3.0V, wait	9	15	21	kHz
Oscillating Frequency	Fϕ OP	—	—	V_{SS} = −3.0V, operate	48	80	112	kHz
Fram Frequency	f_F	—	—	V_{SS} = −3.0V, wait	70	117	164	Hz
Timer	T timer	—	—	V_{SS} = −3.0V	430	603	1005	s
"1" Input Voltage	V_{IH}	—	K_1~K_4 RESET	—	V_{SS} +0.5	—	V_{SS}	V
"0" Input Voltage	V_{IL}	—	K_1~K_4 RESET	—	V_{DD}	—	−0.5	V
"1" Output Resistance	R_{KEY}	—	SEG	V_{OUT} = V_{SS} + 0.5V : KEY STROBE	—	—	2	kΩ
"0" Output Resistance	R_{SEG} (L)	—	SEG	V_{OUT} = V_{DD} − 0.5V	—	—	90	kΩ
"1" Output Resistance	R_{SEG} (H)	—	SEG	V_{OUT} = V_{SS} + 0.5V : $\overline{\text{KEY STROBE}}$	—	—	90	kΩ
"0" Output Resistance	R_{COM} (L)	—	COM	V_{OUT} = V_{DD} − 0.5V	—	—	25	kΩ
"1" Output Resistance	R_{COM} (H)	—	COM	V_{OUT} = V_{SS} + 0.5V	—	—	25	kΩ
KEY Pull Up Resistance	$R_{PULL\ UP}$	—	K_1	V_{OUT} = 0V (Note 1)	27	45	63	kΩ
KEY Pull Down Resistance	$R_{PULL\ DOWN}$	—	K_2~K_4	V_{OUT} = V_{SS} (Note 1)	27	45	63	kΩ
KEY Pull Up Resistance	R_{RESET} (H)	—	RESET	V_{OUT} = 0V	24	40	56	kΩ
KEY Pull Down Resistance	R_{RESET} (L)	—	RESET	V_{OUT} = V_{DD} − 0.5V	—	—	10	kΩ
"M" Output Resistance	R_{OM}	—	SEG	$V_{OUT} = \frac{1}{3}V_{SS} - 0.5V$	—	125	—	kΩ
"M" Output Resistance	R_{OM}	—	SEG	$V_{OUT} = \frac{2}{3}V_{SS} + 0.5V$	—	125	—	kΩ
"M" Output Resistance	R_{OM}	—	COM	$V_{OUT} = \frac{1}{3}V_{SS} - 0.5V$	—	85	—	kΩ
"M" Output Resistance	R_{OM}	—	COM	$V_{OUT} = \frac{2}{3}V_{SS} + 0.5V$	—	85	—	kΩ
"1" Output Voltage	V_{OH}	—	RESET	—	V_{SS} +0.2	V_{SS}	V_{SS}	V

CHARACTERISTICS	SYMBOL	TEST CIR-CUIT	PIN NAME	TEST CONDITION	MIN	TYP.	MAX	UNIT
"0" Output Voltage	V_{OL}	—	RESET	—	V_{DD}	V_{DD}	V_{DD} − 0.2	V
"1" Output Voltage	V_{OH}	—	K_1	(Note 1)	V_{SS} + 0.2	V_{SS}	V_{SS}	V
"0" Output Voltage	V_{OL}	—	K_2~K_4	(Note 1)	V_{DD}	V_{DD}	V_{DD} − 0.2	V
"1" Output Voltage	V_{OH}	—	SEG COM	—	V_{SS} + 0.2	V_{SS}	V_{SS}	V
"M" Output Voltage	V_{OM}	—	SEG COM	—	2 / 3 V_{SS} + 0.2	2 / 3 V_{SS}	2 / 3 V_{SS} − 0.2	V
"M" Output Voltage	V_{OM}	—	SEG COM	—	1 / 3 V_{SS} + 0.2	1 / 3 V_{SS}	1 / 3 V_{SS} − 0.2	V
"0" Output Voltage	V_{OL}	—	SEG COM	—	V_{DD}	V_{DD}	V_{DD} − 0.2	V

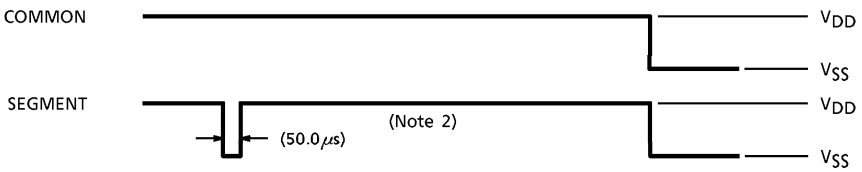
(Note 1) The key buffer is high impedance at $\overline{\text{keystrobe}}$.

WAVEFORMS FOR DISPLAY

Display



Key pulse output



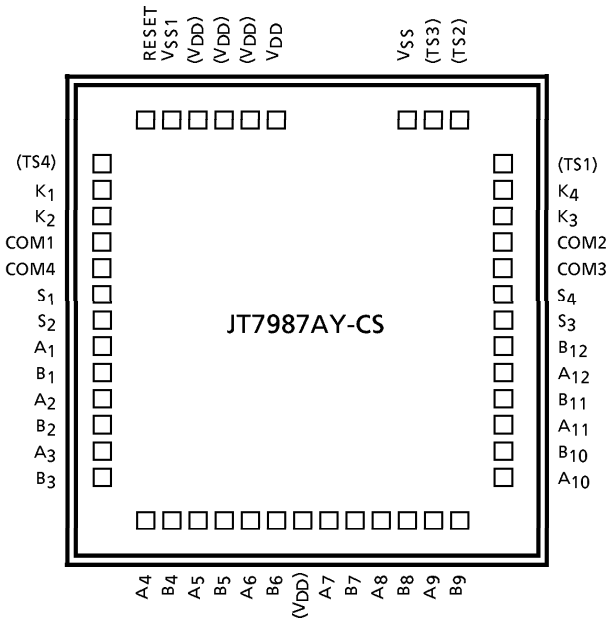
(Note 1) FϕWAIT = 15kHz
(Note 2) FϕOP = 80kHz

PAD LOCATION TABLE (μm)

NAME	X POINT	Y POINT
RESET	– 890	1451
V_{SS1}	– 731	1451
(V_{DD})	– 505	1451
(V_{DD})	– 346	1451
(V_{DD})	– 186	1451
V_{DD}	8	1451
V_{SS}	574	1451
(TS3)	734	1451
(TS2)	1055	1451
(TS1)	1270	993
K_4	1270	829
K_3	1270	666
COM2	1270	503
COM3	1270	339
S_4	1270	175
S_3	1270	13
B_{12}	1270	– 149
A_{12}	1270	– 315
B_{11}	1270	– 478
A_{11}	1270	– 641
B_{10}	1270	– 805
A_{10}	1270	– 968
B_9	1076	– 1414
A_9	888	– 1414
B_8	715	– 1414
A_8	553	– 1414
B_7	390	– 1414
A_7	228	– 1414
(V_{DD})	0	– 1414
B_6	– 231	– 1414
A_6	– 393	– 1414
B_5	– 555	– 1414
A_5	– 717	– 1414
B_4	– 879	– 1414
A_4	– 1069	– 1414
B_3	– 1270	– 958
A_3	– 1270	– 795
B_2	– 1270	– 631
A_2	– 1270	– 468
B_1	– 1270	– 304
A_1	– 1270	– 141
S_2	– 1270	23
S_1	– 1270	186
COM4	– 1270	350
COM1	– 1270	513
K_2	– 1270	676
K_1	– 1270	840
(TS4)	– 1270	1003

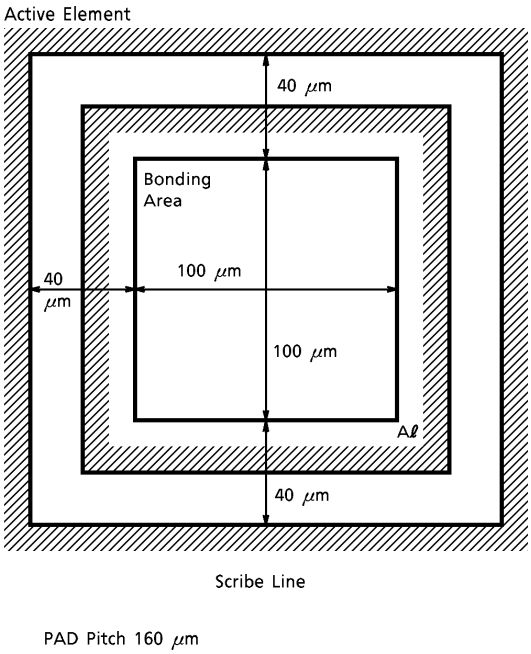
(Note) ( ) Do not connect.

CHIP LAYOUT



Chip size : 2.99 × 3.33 (mm)
Chip thickness : 200 ± 30 (μm)
Substrate : V_{DD}

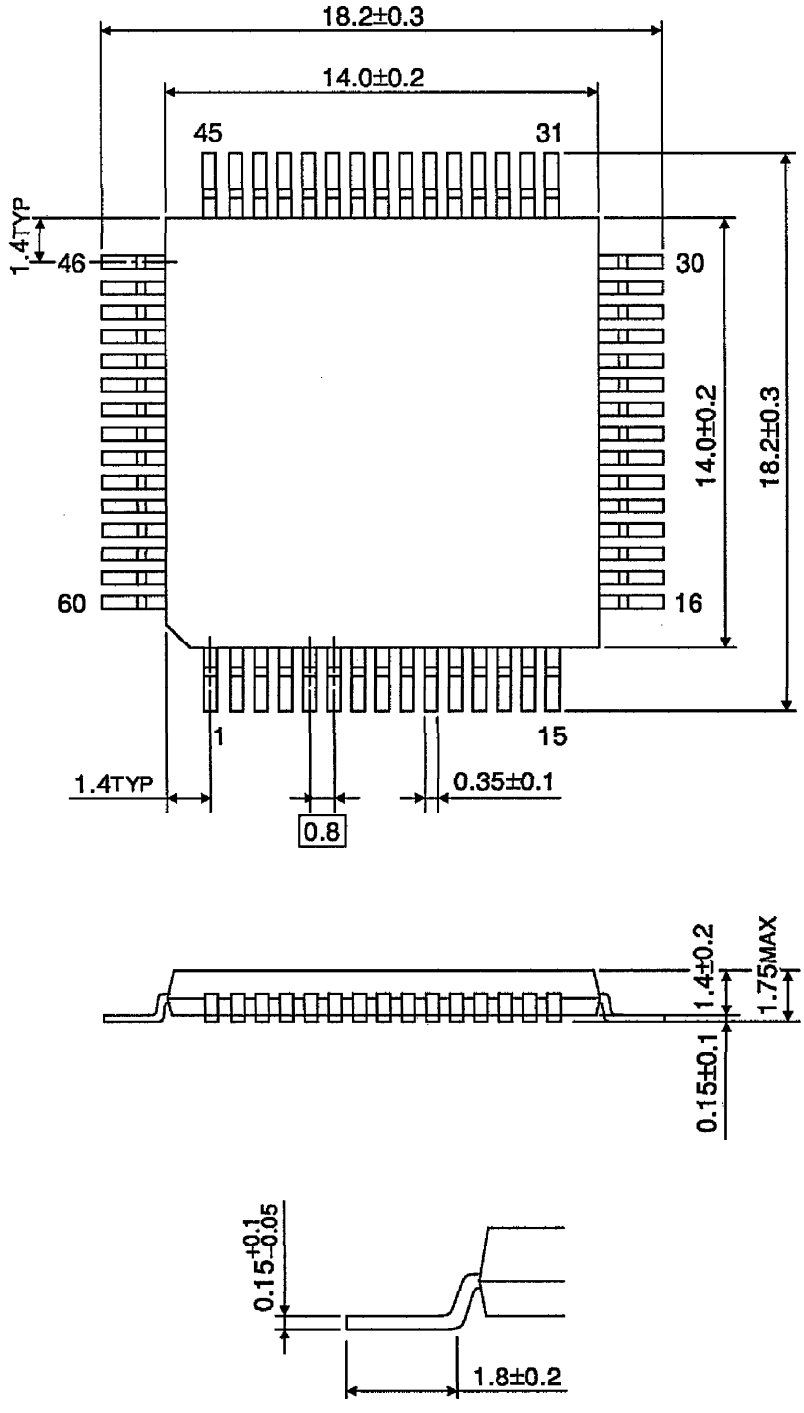
PAD LAYOUT



PAD Pitch 160 μm

PACKAGE DIMENSIONS

LQFP60-P-1414-0.80 Unit : mm



Weight : 0.66g (Typ.)

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000707EBA

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