National Semiconductor

COP444L/COP445L/COP344L/COP345L Single-Chip N-Channel Microcontrollers

General Description

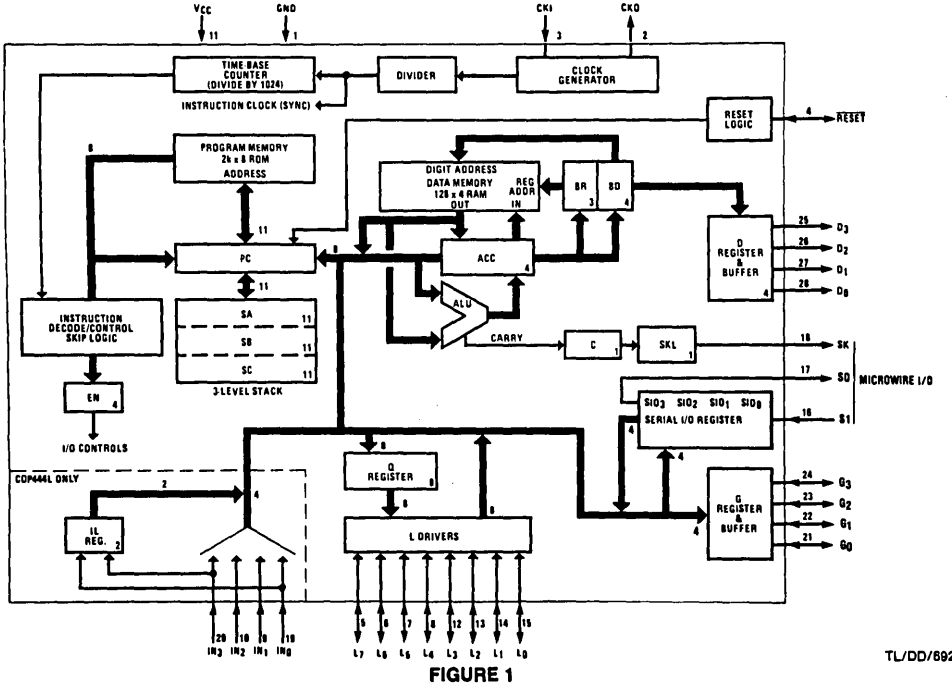
The COP444L, COP445L, COP344L, and COP345L Single-Chip N-Channel Microcontrollers are members of the COPS™ family, fabricated using N-channel, silicon gate MOS technology. These controller oriented processors are complete microcomputers containing all system timing, internal logic, ROM, RAM, and I/O necessary to implement dedicated control functions in a variety of applications. Features include single supply operation, a variety of output configuration options, with an instruction set, internal architecture and I/O scheme designed to facilitate keyboard input, display output and BCD data manipulation. The COP445L is identical to the COP444L, but with 19 I/O lines instead of 23. They are an appropriate choice for use in numerous human interface control environments. Standard test procedures and reliable high-density fabrication techniques provide the medium to large volume customers with a customized controller oriented processor at a low end-product cost.

The COP344L and COP345L are exact functional equivalents, but extended temperature range versions of the COP444L and COP445L respectively.

Features

- Low cost
- Powerful instruction set
- 2k x 8 ROM, 128 x 4 RAM
- 23 I/O lines (COP444L)
- True vectored interrupt, plus restart
- Three-level subroutine stack
- 15 μs instruction time
- Single supply operation (4.5–6.3V)
- Low current drain (11 mA max.)
- Internal time-base counter for real-time processing
- Internal binary counter register with MICROWIRE™ serial I/O capability
- General purpose and TRI-STATE® outputs
- LSTTL/CMOS compatible in and out
- Direct drive of LED digit and segment lines
- Software/hardware compatible with other members of COP400 family
- Extended temperature range devices COP344L/COP345L (−40°C to +85°C)

Block Diagram



TL/DD/6928–1

FIGURE 1

COP444L/COP445L

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Voltage at Any Pin Relative to GND	−0.5V to +10V
Ambient Operating Temperature	0°C to +70°C
Ambient Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C
Power Dissipation	0.75 Watt at 25°C
	0.4 Watt at 70°C
Total Source Current	120 mA
Total Sink current	120 mA

Absolute maximum ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications are not ensured when operating the device at absolute maximum ratings.

DC Electrical Characteristics $0°C \le T_A \le +70°C$, $4.5V \le V_{CC} \le 6.3V$ unless otherwise noted.

Parameter	Conditions	Min	Max	Units
Standard Operating Voltage (V_{CC})	(Note 1)	4.5	6.3	V
Power Supply Ripple	Peak to Peak		0.5	V
Operating Supply Current	All Inputs and Outputs Open		13	mA
Input Voltage Levels				
CKI Input Levels				
Crystal Input (÷32, ÷16, ÷8)				
Logic High (V_{IH})	V_{CC} = Max.	3.0		V
Logic High (V_{IH})	V_{CC} = 5V ±5%	2.0	0.4	V
Logic Low (V_{IL})		−0.3		
Schmitt Trigger Input (÷4)				
Logic High (V_{IH})		0.7 V_{CC}		V
Logic Low (V_{IL})		−0.3	0.6	V
$\overline{\text{RESET}}$ Input Levels	Schmitt Trigger Input			
Logic High		0.7 V_{CC}		V
Logic Low		−0.3	0.6	V
SO Input Level (Test Mode)	(Note 3)	2.0	2.5	V
All Other Inputs				
Logic High	V_{CC} = Max.	3.0		V
Logic High	With TTL Trip Level Options	2.0		V
Logic Low	Selected, V_{CC} = 5V ±10%	−0.3	0.8	V
Logic High	With High Trip Level Options	3.6		V
Logic Low	Selected	−0.3	1.2	V
Input Capacitance			7	pF
Hi-Z Input Leakage		−1	+1	μA
Output Voltage Levels				
LSTTL Operation	V_{CC} = 5V ±5%			
Logic High (V_{OH})	I_{OH} = −25 μA	2.7		V
Logic Low (V_{OL})	I_{OL} = 0.36 mA		0.4	V
CMOS Operation (Note 2)				
Logic High	I_{OH} = −10 μA	V_{CC}−1		V
Logic Low	I_{OL} = +10μA		0.2	V

Note 1: V_{CC} voltage change must be less than 0.5V in a 1 ms period to maintain proper operation.

Note 2: TRI-STATE and LED configurations are excluded.

Note 3: SO output "0" level must be less than 0.8V for normal operation.

COP444L/COP445L (Continued)

DC Electrical Characteristics $0°C \le T_A \le +70°C$, $4.5V \le V_{CC} \le 6.3V$ unless otherwise noted. (Continued)

Parameter	Conditions	Min	Max	Units
Output Current Levels				
Output Sink Current				
SO and SK Outputs (I_{OL})	$V_{CC} = 6.3V, V_{OL} = 0.4V$	1.2		mA
	$V_{CC} = 4.5V, V_{OL} = 0.4V$	0.9		mA
L_0–L_7 Outputs and Standard	$V_{CC} = 6.3V, V_{OL} = 0.4V$	0.4		mA
G_0–G_3, D_0–D_3 Outputs (I_{OL})	$V_{CC} = 4.5V, V_{OL} = 0.4V$	0.4		mA
G_0–G_3 and D_0–D_3 Outputs with	$V_{CC} = 6.3V, V_{OL} = 1.0V$	11		mA
High Current Options (I_{OL})	$V_{CC} = 4.5V, V_{OL} = 1.0V$	7.5		mA
G_0–G_3 and D_0–D_3 Outputs with	$V_{CC} = 6.3V, V_{OL} = 1.0V$	22		mA
Very High Current Options (I_{OL})	$V_{CC} = 4.5V, V_{OL} = 1.0V$	15		mA
CKI (Single-pin RC oscillator)	$V_{CC} = 4.5V, V_{IH} = 3.5V$	2		mA
CKO	$V_{CC} = 4.5V, V_{OL} = 0.4V$	0.2		mA
Output Source Current				
Standard Configuration,	$V_{CC} = 6.3V, V_{OH} = 2.0V$	−75	−480	μA
All Outputs (I_{OH})	$V_{CC} = 4.5V, V_{OH} = 2.0V$	−30	−250	μA
Push-Pull Configuration	$V_{CC} = 9.5V, V_{OH} = 4.75V$	−1.4		mA
SO and SK Outputs (I_{OH})	$V_{CC} = 6.3V, V_{OH} = 2.4V$	−1.4		mA
	$V_{CC} = 4.5V, V_{OH} = 1.0V$	−1.2		mA
LED Configuration, L_0–L_7 Outputs, Low Current Drivers Option (I_{OH})	$V_{CC} = 6.0V, V_{OH} = 2.0V$	−1.5	−13	mA
LED Configuration, L_0–L_7 Outputs, High Current Driver Option (I_{OH})	$V_{CC} = 6.0V, V_{OH} = 2.0V$	−3.0	−25	mA
TRI-STATE Configuration, L_0–L_7 Outputs, Low	$V_{CC} = 6.3V, V_{OH} = 3.2V$	−0.8		mA
Current Driver Option (I_{OH})	$V_{CC} = 4.5V, V_{OH} = 1.5V$	−0.9		mA
TRI-STATE Configuration, L_0–L_7 Outputs, High	$V_{CC} = 6.3V, V_{OH} = 3.2V$	−1.6		mA
Current Driver Option (I_{OH})	$V_{CC} = 4.5V, V_{OH} = 1.5V$	−1.8		mA
Input Load Source Current	$V_{CC} = 5.0V$	−10	−140	μA
CKO Output				
RAM Power Supply Option				
Power Requirement	$V_R = 3.3V$		3.0	mA
TRI-STATE Output Leakage Current		−2.5	+2.5	μA
Total Sink Current Allowed				
All Outputs Combined			120	mA
D, G Ports			120	mA
L_7–L_4			4	mA
L_3–L_0			4	mA
All Other Pins			1.5	mA
Total Source Current Allowed				
All I/O Combined			120	mA
L_7–L_4			60	mA
L_3–L_0			60	mA
Each L Pin			30	mA
All Other Pins			1.5	mA

COP344L/COP345L

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Voltage at Any Pin Relative to GND	−0.5V to +10V
Ambient Operating Temperature	−40°C to +85°C
Ambient Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C
Power Dissipation	0.75 Watt at 25°C 0.25 Watt at 85°C
Total Source Current	120 mA
Total Sink Current	120 mA

Absolute maximum ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications are not ensured when operating the device at absolute maximum ratings.

DC Electrical Characteristics

$-40°C \le T_A \le +85°C$, $4.5V \le V_{CC} \le 5.5V$ unless otherwise noted.

Parameter	Conditions	Min	Max	Units
Standard Operating Voltage (V_{CC})	(Note 1)	4.5	5.5	V
Power Supply Ripple	Peak to Peak		0.5	V
Operating Supply Current	All Inputs and Outputs Open		15	mA
Input Voltage Levels				
CKI Input Levels				
Crystal Input				
Logic High (V_{IH})	V_{CC} = Max.	3.0		V
Logic High (V_{IH})	V_{CC} = 5V ±5%	2.2	0.3	V
Logic Low (V_{IL})		−0.3		
Schmitt Trigger Input				
Logic High (V_{IH})		0.7 V_{CC}		V
Logic Low (V_{IL})		−0.3	0.4	V
$\overline{\text{RESET}}$ Input Levels	Schmitt Trigger Input			
Logic High		0.7 V_{CC}		V
Logic Low		−0.3	0.4	V
SO Input Level (Test Mode)		2.2	2.5	V
All Other Inputs				
Logic High	V_{CC} = Max.	3.0		V
Logic High	With TTL Trip Level Options	2.2		V
Logic Low	Selected, V_{CC} = 5V ±5%	−0.3	0.6	V
Logic High	With High Trip Level Options	3.6		V
Logic Low	Selected	−0.3	1.2	V
Input Capacitance			7	pF
Hi-Z Input Leakage		−2	+2	μA
Output Voltage Levels				
LSTTL Operation	V_{CC} = 5V ±10%			
Logic High (V_{OH})	I_{OH} = −20 μA	2.7		V
Logic Low (V_{OL})	I_{OL} = 0.36 mA		0.4	V
CMOS Operation (Note 2)				
Logic High	I_{OH} = −10 μA	V_{CC}−1		V
Logic Low	I_{OL} = +10 μA		0.2	V

Note 1: V_{CC} voltage change must be less than 0.5V in a 1 ms period to maintain proper operation.

Note 2: TRI-STATE and LED configurations are excluded.

Note 3: SO output "0" level must be less than 0.6V for normal operation.

COP344L/COP345L (Continued)

DC Electrical Characteristics

$-40°C \le T_A \le +85°C$, $4.5V \le V_{CC} \le 5.5V$ unless otherwise noted. (Continued)

Parameter	Conditions	Min	Max	Units
Output Current Levels				
Output Sink Current				
SO and SK Outputs (I_{OL})	$V_{CC} = 5.5V, V_{OL} = 0.4V$	1.0		mA
	$V_{CC} = 4.5V, V_{OL} = 0.4V$	0.8		mA
L_0–L_7 Outputs, and Standard	$V_{CC} = 5.5V, V_{OL} = 0.4V$	0.4		mA
G_0–G_3, D_0–D_3 Outputs (I_{OL})	$V_{CC} = 4.5V, V_{OL} = 0.4V$	0.4		mA
G_0–G_3 and D_0–D_3 Outputs with	$V_{CC} = 5.5V, V_{OL} = 1.0V$	9		mA
High Current Options (I_{OL})	$V_{CC} = 4.5V, V_{OL} = 1.0V$	7		mA
G_0–G_3 and D_0–D_3 Outputs with	$V_{CC} = 5.5V, V_{OL} = 1.0V$	18		mA
Very High Current Options (I_{OL})	$V_{CC} = 4.5V, V_{OL} = 1.0V$	14		mA
CKI (Single-Pin RC Oscillator)	$V_{CC} = 4.5V, V_{IH} = 3.5V$	2		mA
CKO	$V_{CC} = 4.5V, V_{OL} = 0.4V$	0.2		mA
Output Source Current				
Standard Configuration,	$V_{CC} = 5.5V, V_{OH} = 2.0V$	−55	−600	μA
All Outputs (I_{OH})	$V_{CC} = 4.5V, V_{OH} = 2.0V$	−28	−350	μA
Push-Pull Configuration	$V_{CC} = 5.5V, V_{OH} = 2.0V$	−1.1		mA
SO and SK Outputs (I_{OH})	$V_{CC} = 4.5V, V_{OH} = 1.0V$	−1.2		mA
LED Configuration, L_0–L_7				
Outputs, Low Current	$V_{CC} = 6.0V, V_{OH} = 2.0V$	−1.4	−17	mA
Driver Option(I_{OH})	$V_{CC} = 5.5V, V_{OH} = 2.0V$	−0.7	−15	mA
LED Configuration, L_0–L_7				
Outputs, High Current	$V_{CC} = 6.0V, V_{OH} = 2.0V$	−2.7	−34	mA
Driver Option (I_{OH})	$V_{CC} = 5.5V, V_{OH} = 2.0V$	−1.4	−30	mA
TRI-STATE Configuration,				
L_0–L_7 Outputs, Low	$V_{CC} = 5.5V, V_{OH} = 2.7V$	−0.6		mA
Current Driver Option (I_{OH})	$V_{CC} = 4.5V, V_{OH} = 1.5V$	−0.9		mA
TRI-STATE Configuration,				
L_0–L_7 Outputs, High	$V_{CC} = 5.5V, V_{OH} = 2.7V$	−1.2		mA
Current Driver Option (I_{OH})	$V_{CC} = 4.5V, V_{OH} = 1.5V$	−1.8		mA
Input Load Source Current	$V_{CC} = 5.0V$	−10	−200	μA
CKO Output				
RAM Power Supply Option	$V_R = 3.3V$		4.0	mA
Power Requirement				
TRI-STATE Output Leakage Current		−5	+5	μA
Total Sink Current Allowed				
All Outputs Combined			120	mA
D, G Ports			120	mA
L_7–L_4			4	mA
L_3–L_0			4	mA
All Other Pins			1.5	mA
Total Source Current Allowed				
All I/O Combined			120	mA
L_7–L_4			60	mA
L_3–L_0			60	mA
Each L Pin			30	mA
All Other Pins			1.5	mA

AC Electrical Characteristics

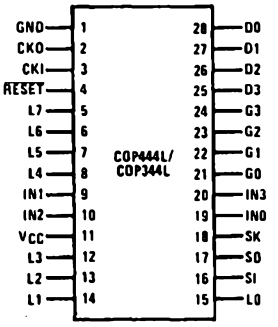
COP444L/445L: $0°C \leq T_A \leq 70°C$, $4.5V \leq V_{CC} \leq 6.3V$ unless otherwise noted.
COP344L/345L: $-40°C \leq T_A \leq +85°C$, $4.5V \leq V_{CC} \leq 5.5V$ unless otherwise noted.

Parameter	Conditions	Min	Max	Units
Instruction Cycle Time—t_C		16	40	μs
CKI				
Input Frequency—f_I	÷32 Mode	0.8	2.0	MHz
	÷16 Mode	0.4	1.0	MHz
	÷8 Mode	0.2	0.5	MHz
	÷4 Mode	0.1	0.25	MHz
Duty Cycle		30	60	%
Rise Time	f_I = 2 MHz		120	ns
Fall Time			80	ns
CKI Using RC (÷4)	R = 56 kΩ ±5% C = 100 pF ±10%			
Instruction Cycle Time (Note 1)		16	28	μs
CKO as SYNC Input				
t_{SYNC}		400		ns
INPUTS:				
IN_3–IN_0, G_3–G_0, L_7–L_0				
t_{SETUP}		8.0		μs
t_{HOLD}		1.3		μs
SI				
t_{SETUP}		2.0		μs
t_{HOLD}		1.0		μs
OUTPUT PROPAGATION DELAY	Test Condition: C_L = 50 pF, R_L = 20 kΩ, V_{OUT} = 1.5V			
SO, SK Outputs				
t_{pd1}, t_{pd0}			4.0	μs
All Other Outputs				
t_{pd1}, t_{pd0}			5.6	μs

Note 1: Variation due to the device included.

Connection Diagrams

Dual-In-Line

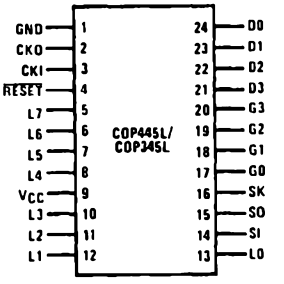


TL/DD/6928-2

Top View

Order Number COP444L-XXX/N or COP344L-XXX/N
See NS Package Number N28B

Dual-In-Line



TL/DD/6928-3

Top View

Order Number COP445L-XXX/N or COP345L-XXX/N
See NS Package Number N24A

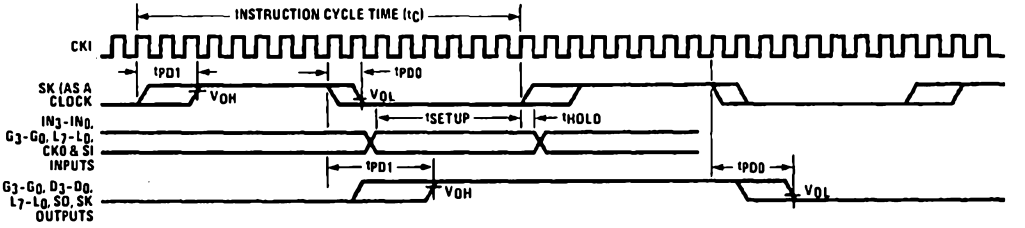
FIGURE 2

Pin Descriptions

Pin	Description
L_7–L_0	8 bidirectional I/O ports with TRI-STATE
G_3–G_0	4 bidirectional I/O ports
D_3–D_0	4 general purpose outputs
IN_3–IN_0	4 general purpose inputs (COP444L only)
SI	Serial input (or counter input)
SO	Serial output (or general purpose output)
SK	Logic-controlled clock (or general purpose output)

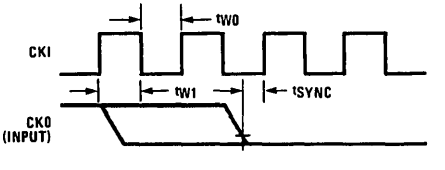
Pin	Description
CKI	System oscillator input
CKO	System oscillator output (or general purpose input, RAM power supply, or SYNC input)
$\overline{RESET}$	System reset input
V_{CC}	Power supply
GND	Ground

Timing Diagrams



TL/DD/6928-4

FIGURE 3a. Input/Output Timing Diagrams (Crystal Divide-by-16 Mode)



TL/DD/6928-5

FIGURE 3b. Synchronization Timing

Functional Description

A block diagram of the COP444L is given in *Figure 1*. Data paths are illustrated in simplified form to depict how the various logic elements communicate with each other in implementing the instruction set of the device. Positive logic is used. When a bit is set, it is a logic "1" (greater than 2 volts). When a bit is reset, it is a logic "0" (less than 0.8 volts).

All functional references to the COP444L/COP445L also apply to the COP344L/COP345L.

PROGRAM MEMORY

Program Memory consists of a 2048 byte ROM. As can be seen by an examination of the COP444L/445L instruction set, these words may be program instructions, program data or ROM addressing data. Because of the special characteristics associated with the JP, JSRP, JID, and LQID instructions, ROM must often be thought of as being organized into 32 pages of 64 words each.

ROM addressing is accomplished by a 11-bit PC register. Its binary value selects one of the 2048 8-bit words contained in ROM. A new address is loaded into the PC register during each instruction cycle. Unless the instruction is a transfer of control instruction, the PC register is loaded with the next sequential 11-bit binary count value. Three levels of subroutine nesting are implemented by the 11-bit subroutine save registers, SA, SB, and SC, providing a last-in, first-out (LIFO) hardware subroutine stack.

ROM instruction words are fetched, decoded and executed by the Instruction Decode, Control and Skip Logic circuitry.

DATA MEMORY

Data memory consists of a 512-bit RAM, organized as 8 data registers of 16 4-bit digits. RAM addressing is implemented by a 7-bit B register whose upper 3 bits (Br) select 1 of 8 data registers and lower 4 bits (Bd) select 1 of 16 4-bit digits in the selected data register. While the 4-bit contents of the selected RAM digit (M) is usually loaded into or from, or exchanged with, the A register (accumulator), it may also be loaded into or from the Q latches or loaded from the L ports. RAM addressing may also be performed directly by the LDD and XAD instructions based upon the 7-bit contents of the operand field of these instructions. The Bd register also serves as a source register for 4-bit data sent directly to the D outputs.

INTERNAL LOGIC

The 4-bit A register (accumulator) is the source and destination register for most I/O, arithmetic, logic and data memory access operations. It can also be used to load the Br and Bd portions of the B register, to load and input 4 bits of the 8-bit Q latch data, to input 4 bits of the 8-bit L I/O port data and to perform data exchanges with the SIO register.

A 4-bit adder performs the arithmetic and logic functions, storing its results in A. It also outputs a carry bit to the 1-bit C register, most often employed to indicate arithmetic overflow. The C register, in conjunction with the XAS instruction and the EN register, also serves to control the SK output. C can be outputted directly to SK or can enable SK to be a sync clock each instruction cycle time. (See XAS instruction and EN register descriptor, below.)

Four general-purpose inputs, IN_3–IN_0, are provided.

The D register provides 4 general-purpose outputs and is used as the destination register for the 4-bit contents of Bd. The D outputs can be directly connected to the digits of a multiplexed LED display.

The G register contents are outputs to 4 general-purpose bidirectional I/O ports. G I/O ports can be directly connected to the digits of a multiplexed LED display.

The Q register is an internal, latched, 8-bit register, used to hold data loaded to or from M and A, as well as 8-bit data from ROM. Its contents are output to the L I/O ports when the L drivers are enabled under program control. (See LEI instruction.)

The 8 L drivers, when enabled, output the contents of latched Q data to the L I/O ports. Also, the contents of L may be read directly into A and M. L I/O ports can be directly connected to the segments of a multiplexed LED display (using the LED Direct Drive output configuration option) with Q data being outputted to the Sa–Sg and decimal point segments of the display.

The SIO register functions as a 4-bit serial-in/serial-out shift register or as a binary counter depending on the contents of the EN register. (See EN register description, below.) Its contents can be exchanged with A, allowing it to input or output a continuous serial data stream. SIO may also be used to provide additional parallel I/O by connecting SO to external serial-in/parallel-out shift registers.

The XAS instruction copies C into the SKL latch. In the counter mode, SK is the output of SKL; in the shift register mode, SK outputs SKL ANDed with the clock.

The EN register is an internal 4-bit register loaded under program control by the LEI instruction. The state of each bit of this register selects or deselects the particular feature associated with each bit of the EN register (EN_3–EN_0).

1. The least significant bit of the enable register, EN_0, selects the SIO register as either a 4-bit shift register or a 4-bit binary counter. With EN_0 set, SIO is an asynchronous binary counter, *decrementing* its value by one upon each low-going pulse ("1" to "0") occurring on the SI input. Each pulse must be at least two instruction cycles wide. SK outputs the value of SKL. The SO output is equal to the value of EN_3. With EN_0 reset, SIO is a serial shift register shifting left each instruction cycle time. The data present at SI goes into the least significant bit of SIO. SO can be enabled to output the most significant bit of SIO each cycle time. (See 4 below.) The SK output becomes a logic-controlled clock.
2. With EN_1 set the IN_1 input is enabled as an interrupt input. Immediately following an interrupt, EN_1 is reset to disable further interrupts.
3. With EN_2 set, the L drivers are enabled to output the data in Q to the L I/O ports. Resetting EN_2 disables the L drivers, placing the L I/O ports in a high-impedance input state.
4. EN_3, in conjunction with EN_0, affects the SO output. With EN_0 set (binary counter option selected) SO will output the value loaded into EN_3. With EN_0 reset (serial shift register option selected), setting EN_3 enables SO as the output of the SIO shift register, outputting serial shifted data each instruction time. Resetting EN_3 with the serial shift register option selected disables SO as the shift register output; data continues to be shifted through SIO and can be exchanged with A via an XAS instruction but SO remains reset to "0". The table below provides a summary of the modes associated with EN_3 and EN_0.

Functional Description (Continued)

Enable Register Modes—Bits EN_3 and EN_0

EN_3	EN_0	SIO	SI	SO	SK
0	0	Shift Register	Input to Shift Register	0	If SKL = 1, SK = CLOCK If SKL = 0, SK = 0
1	0	Shift Register	Input to Shift Register	Serial Out	If SKL = 1, SK = CLOCK If SKL = 0, SK = 0
0	1	Binary Counter	Input to Binary Counter	0	If SKL = 1, SK = 1 If SKL = 0, SK = 0
1	1	Binary Counter	Input to Binary Counter	1	If SKL = 1, SK = 1 If SKL = 0, SK = 0

INTERRUPT

The following features are associated with the IN_1 interrupt procedure and protocol and must be considered by the programmer when utilizing interrupts.

a. The interrupt, once acknowledged as explained below, pushes the next sequential program counter address (PC+1) onto the stack, pushing in turn the contents of the other subroutine-save registers to the next lower level (PC + 1 → SA → SB → SC). Any previous contents of SC are lost. The program counter is set to hex address 0FF (the last word of page 3) and EN_1 is reset.

b. An interrupt will be acknowledged only after the following conditions are met:

1. EN_1 has been set.
2. A low-going pulse ("1" to "0") at least two instruction cycles wide occurs on the IN_1 input.
3. A currently executing instruction has been completed
4. All successive transfer of control instructions and successive LBIs have been completed (e.g., if the main program is executing a JP instruction which transfers program control to another JP instruction, the interrupt will not be acknowledged until the second JP instruction has been executed.

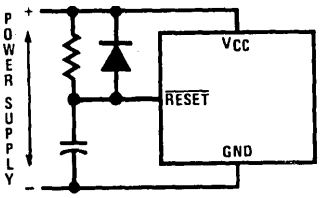
c. Upon acknowledgement of an interrupt, the skip logic status is saved and later restored upon popping of the stack. For example, if an interrupt occurs during the execution of ASC (Add with Carry, Skip on Carry) instruction which results in carry, the skip logic status is saved and program control is transferred to the interrupt servicing routine at hex address 0FF. At the end of the interrupt routine, a RET instruction is executed to "pop" the stack and return program control to the instruction following the original ASC. *At this time*, the skip logic is enabled and skips this instruction because of the previous ASC carry. Subroutines and LQID instructions should not be nested within the interrupt service routine, since their popping the stack will enable any previously saved main program skips, interfering with the orderly execution of the interrupt routine.

d. The first instruction of the interrupt routine at hex address 0FF must be a NOP.

e. A LEI instruction can be put immediately before the RET to re-enable interrupts.

INITIALIZATION

The Reset Logic will initialize (clear) the device upon power-up if the power supply rise time is less than 1 ms and greater than 1 μs. If the power supply rise time is greater than 1 ms, the user use provide an external RC network and diode to the $\overline{RESET}$ pin as shown below. If the RC network is not used, the $\overline{RESET}$ pin must be pulled up to V_{CC} either by the internal load or by an external resistor (≥ 40 kΩ) to V_{CC}. The $\overline{RESET}$ pin is configured as a Schmitt trigger input. Initialization will occur whenever a logic "0" is applied to the $\overline{RESET}$ input, provided it stays low for at least three instruction cycle times.



TL/DD/6928-6

RC ≥ 5 x Power Supply Rise Time (R ≥ 40k)

Power-Up Clear Circuit

Upon initialization, the PC register is cleared to 0 (ROM address 0) and the A, B, C, D, EN, and G registers are cleared. The SK output is enabled as a SYNC output, providing a pulse each instruction cycle time. *Data Memory (RAM) is not cleared upon initialization.* The first instuction at address 0 must be a CLRA.

OSCILLATOR

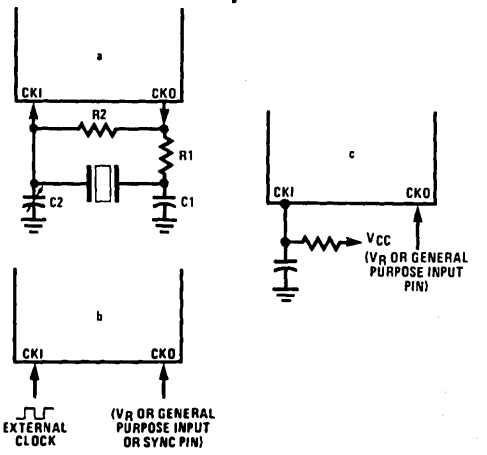
There are four basic clock oscillator configurations available as shown by *Figure 4*.

a. **Crystal Controlled Oscillator.** CKI and CKO are connected to an external crystal. The instruction cycle time equals the crystal frequency divided by 32 (optional by 16 or 8).

b. **External Oscillator.** CKI is an external clock input signal. The external frequency is divided by 32 (optional by 16 or 8) to give the instruction cycle time. CKO is now available to be used as the RAM power supply (V_R), as a general purpose input.

c. **RC Controlled Oscillator.** CKI is configured as a single pin RC controlled Schmitt trigger oscillator. The instruction cycle equals the oscillation frequency divided by 4. CKO is available as the RAM power supply (V_R) or as a general purpose input.

Functional Description (Continued)



TL/DD/6928-7

Crystal Oscillator

Crystal Value	Component Values			
	R1 (Ω)	R2 (Ω)	C1 (pF)	C2 (pF)
455 kHz	4.7k	1M	220	220
2.097 MHz	1k	1M	30	6-36

RC Controlled Oscillator

R (kΩ)	C (pF)	Instruction Cycle Time (μs)
51	100	19 ± 15%
82	56	19 ± 13%

NOTE: 200 kΩ ≥ R ≥ 25 kΩ
360 pF ≥ C ≥ 50 pF

FIGURE 4. COP444L/445L Oscillator

CKO PIN OPTIONS

In a crystal controlled oscillator system, CKO is used as an output to the crystal network. As an option CKO can be a general purpose input, read into bit 2 of A (accumulator) upon execution of an INIL instruction. As another option, CKO can be a RAM power supply pin (V_R), allowing its connection to a standby/backup power supply to maintain the integrity of RAM data with minimum power drain when the main supply is inoperative or shut down to conserve power. Using either option is appropriate in applications where the COP444L/445L system timing configuration does not require use of the CKO pin.

I/O OPTIONS

COP444L/445L outputs have the following optional configurations, illustrated in *Figure 5*.

a. Standard—an enhancement mode device to ground in conjunction with a depletion-mode device to V_{CC}, compatible with LSTTL and CMOS input requirements. Available on SO, SK, and all D and G outputs.

b. Open-Drain—an enhancement-mode device to ground only, allowing external pull-up as required by the user's application. Available on SO, SK, and all D and G outputs.

c. Push-Pull—An enhancement-mode device to ground in conjunction with a depletion-mode device paralleled by an enhancement-mode device to V_{CC}. This configuration has been provided to allow for fast rise and fall times when driving capacitive loads. Available on SO and SK outputs only.

d. Standard L—same as **a.**, but may be disabled. Available on L outputs only.

e. Open Drain L—same as **b.**, but may be disabled. Available on L outputs only.

f. LED Direct Drive—an enhancement-mode device to ground and to V_{CC}, meeting the typical current sourcing requirements of the segments of an LED display. The sourcing device is clamped to limit current flow. These devices may be turned off under program control (See Functional Description, EN Register), placing the outputs in a high impedance state to provide required LED segment blanking for a multiplexed display. Available on L outputs only.

Note: Series current limiting resistors have to be used if the higher operating voltage option is selected and LEDs are driven directly.

g. TRI-STATE Push-Pull—an enhancement-mode device to ground and V_{CC}. These outputs are TRI-STATE outputs, allowing for connection of these outputs to a data bus shared by other bus drivers. Available on L outputs only.

COP444L/COP445L inputs have the following optional configurations:

h. An on-chip depletion load device to V_{CC}.

I. A Hi-Z input which must be driven to a "1" or "0" by external components.

The above input and output configurations share common enhancement-mode and depletion-mode devices. Specifically, all configurations use one or more of six devices (numbered 1-6, respectively). Minimum and maximum current (I_{OUT} and V_{OUT} curves are given in *Figure 6* for each of these devices to allow the designer to effectively use these I/O configurations in designing a system.

The SO, SK outputs can be configured as shown in **a.**, **b.**, or **c.** The D and G outputs can be configured as shown in **a.** or **b.** Note that when inputting data to the G ports, the G outputs should be set to "1". The L outputs can be configured in **d.**, **e.**, **f.** or **g.**

An important point to remember if using configuration **d.** or **f.** with the L drivers is that even when the L drivers are disabled, the depletion load device will source a small amount of current (see *Figure 6*, device 2); however, when the L-lines are used as inputs, the disabled depletion device can *not* be relied on to source sufficient current to pull an input to logic "1".

RAM KEEP-ALIVE OPTION

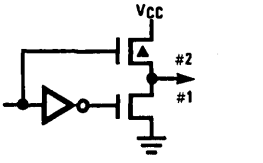
Selecting CKO as the RAM power supply (V_R) allows the user to shut off the chip power supply (V_{CC}) and maintain data in the lower four (Br = 0, 1, 2, 3) registers of RAM. To insure that RAM data integrity is maintained, the following conditions *must* be met:

1. $\overline{\text{RESET}}$ must go low before V_{CC} goes low during power off; V_{CC} must go high before $\overline{\text{RESET}}$ goes high on power-up.
2. V_R must be within the operating range of the chip, and equal to $V_{CC} \pm 1V$ during normal operation.
3. V_R must be ≥ 3.3V with V_{CC} off.

Functional Description (Continued)

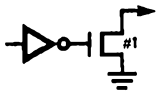
COP445L

If the COP444L is bonded as a 24-pin device, it becomes the COP455L, illustrated in *Figure 2*, COP444L/445L Connection Diagrams. Note that the COP445L does not contain the four general purpose IN inputs (IN_3–IN_0). Use of this option precludes, of course, use of the IN options and the interrupt feature, which uses IN_1. All other options are available for the COP445L.



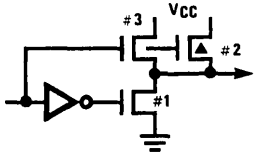
TL/DD/6928-9

a. Standard Output



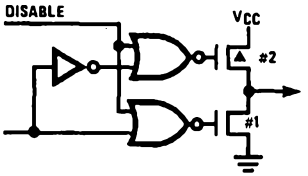
TL/DD/6928-10

b. Open-Drain Output



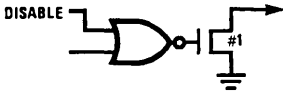
TL/DD/6928-11

c. Push-Pull Output



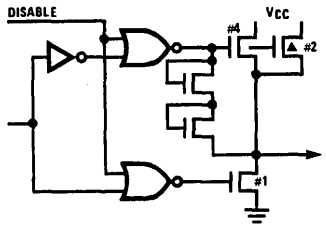
TL/DD/6928-12

d. Standard L Output



TL/DD/6928-13

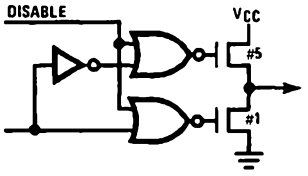
e. Open-Drain L Output



TL/DD/6928-14

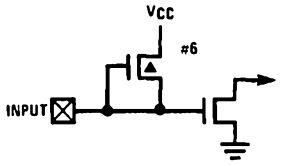
(▲ is Depletion Device)

f. LED (L Output)



TL/DD/6928-15

g. TRI-STATE Push-Pull (L Output)



TL/DD/6928-16

h. Input with Load

TL/DD/6928-17

I. HI-Z Input

FIGURE 5. Output Configuration

L-Bus Considerations

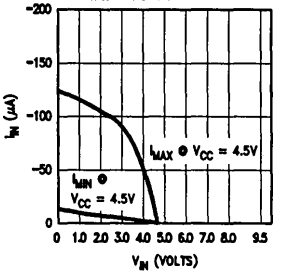
False states may be generated on L_0–L_7 during the execution of the CAMQ instruction. The L-Ports should not be used as clocks for edge sensitive devices such as flip-flops, counters, shift registers, etc. The following short program illustrates this situation.

```
START:
        CLRA            ;ENABLE THE Q
        LEI   4         ;REGISTER TO L LINES
        LBI   TEST
        STII  3
        AISC  12
LOOP:
        LBI   TEST      ;LOAD Q WITH X'C3
        CAMQ
        JP    LOOP
```

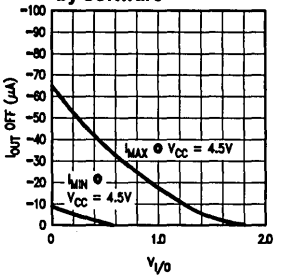
In this program the internal Q register is enabled onto the L lines and a steady bit pattern of logic highs is output on L_0, L_1, L_6, L_7, and logic lows on L_2–L_5 via the two-byte CAMQ instruction. Timing constraints on the device are such that the Q register may be temporarily loaded with the second byte of the CAMQ opcode (X'3C) prior to receiving the valid data pattern. If this occurs, the opcode will ripple onto the L lines and cause negative-going glitches on L_0, L_1, L_6, L_7, and positive glitches on L_2–L_5. Glitch durations are under 2 μs, although the exact value may vary due to data patterns, processing parameters, and the L line loading. These false states are peculiar only to the CAMQ instruction and the L lines.

Typical Performance Characteristics

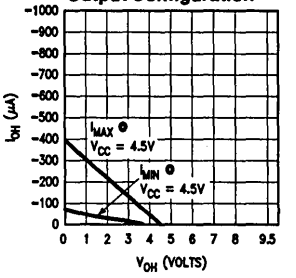
Current for Inputs with Load Device



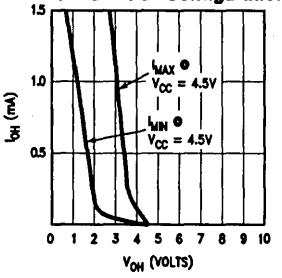
Input Current for L_0 through L_7 when Output Programmed Off by Software



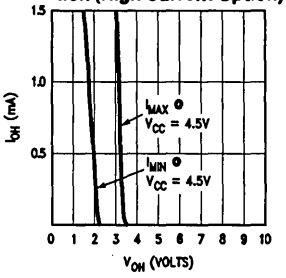
Source Current for Standard Output Configuration



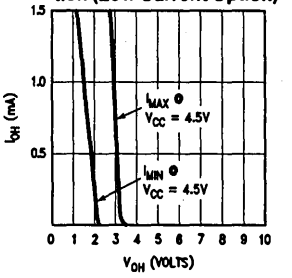
Source Current for SO and SK in Push-Pull Configuration



Source Current for L_0 through L_7 in TRI-STATE Configuration (High Current Option)



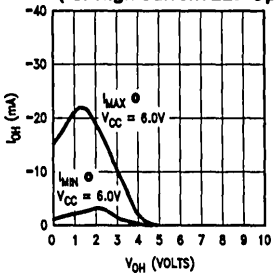
Source Current for L_0 through L_7 in TRI-STATE configuration (Low Current Option)



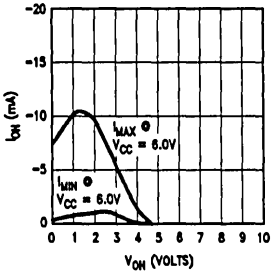
TL/DD/6928–18

Typical Performance Characteristics (Continued)

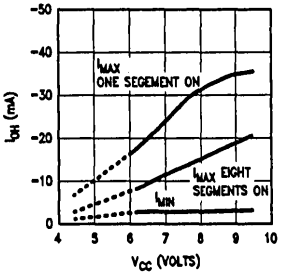
LED Output Source Current (for High Current LED Option)



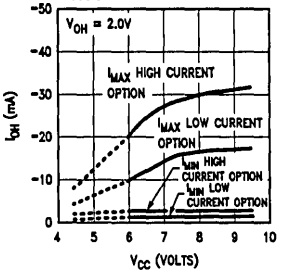
LED Output Source Current (for Low Current LED Option)



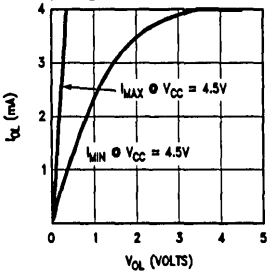
LED Output Direct Segment Drive High Current Options on L_0–L_7 Very High Current Options on D_0–D_3 or G_0–G_3



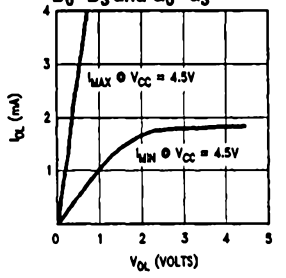
LED Output Direct Segment Drive



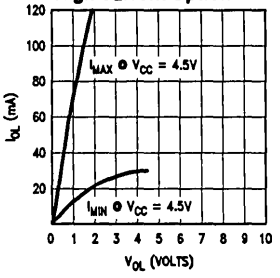
Output Sink Current for SO and SK



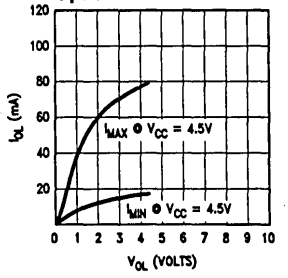
Output Sink Current for L_0–L_7 and Standard Drive Option for D_0–D_3 and G_0–G_3



Output Sink Current G_0–G_3 and D_0–D_3 with Very High Current Option



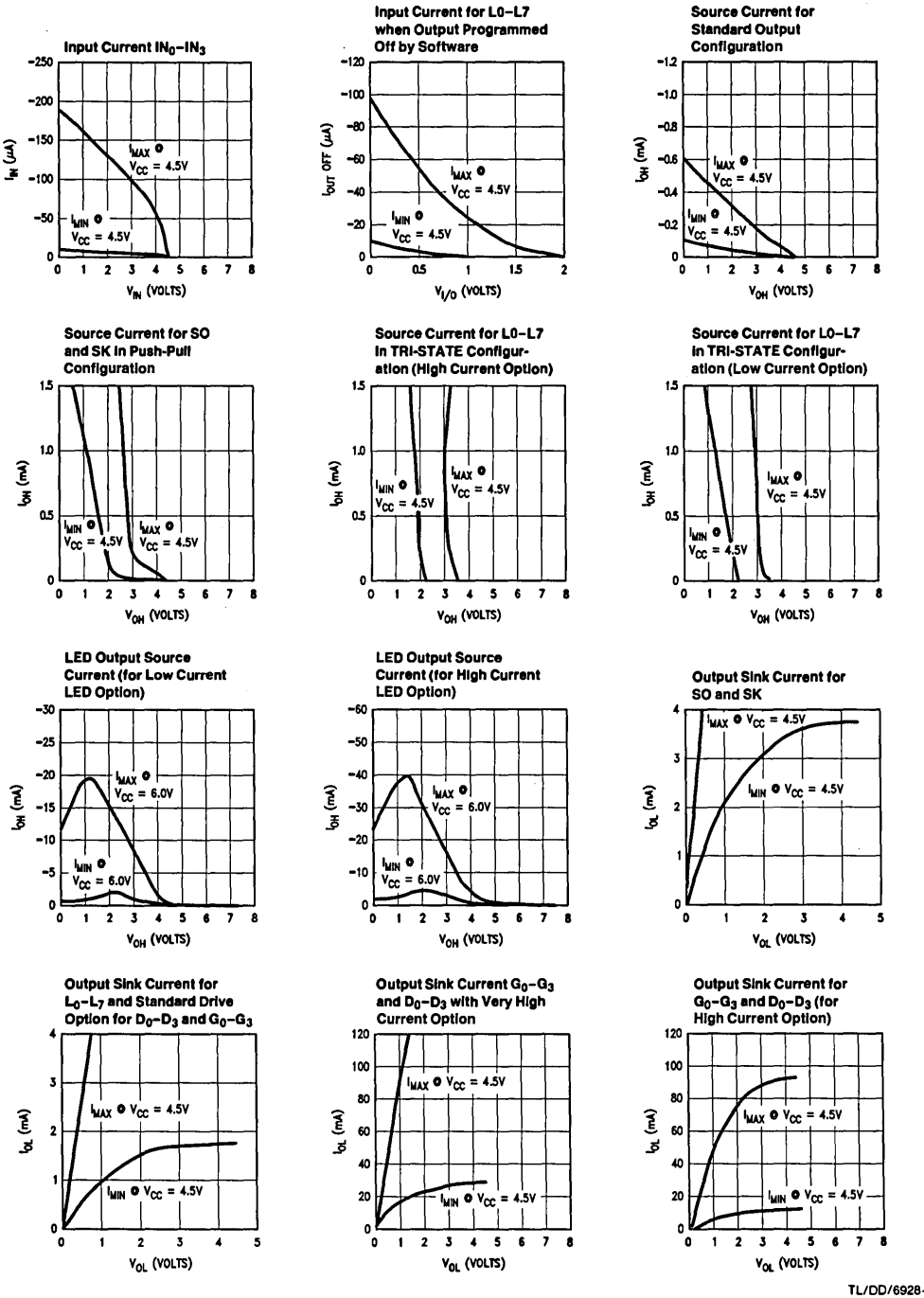
Output Sink Current for G_0–G_3 and D_0–D_3 (for High Current Option



TL/DD/6928–19

FIGURE 6a. COP444L/COP445L Input/Output Characteristics

Typical Performance Characteristics (Continued)



TL/DD/6928–20

FIGURE 6b. COP344L/COP345L Input/Output Characteristics

COP444L/COP445L/COP344L/COP345L Instruction Set

Table I is a symbol table providing internal architecture, instruction operand and operational symbols used in the instruction set table.

Table II provides the mnemonic, operand, machine code, data flow, skip conditions and description associated with each instruction in the COP444L/445L instruction set.

TABLE I. COP444L/445L/344L/345L Instruction Table Symbols

Symbol	Definition
INTERNAL ARCHITECTURE SYMBOLS	
A	4-bit Accumulator
B	6-bit RAM Address Register
Br	Upper 3 bits of B (register address)
Bd	Lower 4 bits of B (digit address)
C	1-bit Carry Register
D	4-bit Data Output Port
EN	4-bit Enable Register
G	4-bit Register to latch data for G I/O Port
IL	Two 1-bit latches associated with the IN_3 or IN_0 inputs
IN	4-bit Input Port
L	8-bit TRI-STATE I/O Port
M	4-bit contents of RAM Memory pointed to by B Register
PC	11-bit ROM Address Register (program counter)
Q	8-bit Register to latch data for L I/O Port
SA	11-bit Subroutine Save Register A
SB	11-bit Subroutine Save Register B
SC	11-bit Subroutine Save Register C
SIO	4-bit Shift Register and Counter
SK	Logic-Controlled Clock Output

Symbol	Definition
INSTRUCTION OPERAND SYMBOLS	
d	4-bit Operand Field, 0-15 binary (RAM Digit Select)
r	3-bit Operand Field, 0-7 binary (RAM Register Select)
a	11-bit Operand Field, 0-2047 binary (ROM Address)
y	4-bit Operand Field, 0-15 binary (Immediate Data)
RAM(s)	Contents of RAM location addressed by s
ROM(t)	Contents of ROM location addressed by t
OPERATIONAL SYMBOLS	
+	Plus
−	Minus
→	Replaces
←→	Is exchanged with
=	Is equal to
$\overline{A}$	The one's complement of A
⊕	Exclusive-OR
:	Range of values

TABLE II. COP444L/445L Instruction Set

Mnemonic	Operand	Hex Code	Machine Language Code (Binary)	Data Flow	Skip Conditions	Description
ARITHMETIC INSTRUCTIONS						
ASC		30	|0011|0000|	A + C + RAM(B) → A Carry → C	Carry	Add with Carry, Skip on Carry
ADD		31	|0011|0001|	A + RAM(B) → A	None	Add RAM to A
ADT		4A	|0100|1010|	A + 10_{10} → A	None	Add Ten to A
AISC	y	5−	|0101| y |	A + y → A	Carry	Add Immediate, Skip on Carry (y ≠ 0)
CASC		10	|0001|0000|	$\overline{A}$ + RAM(B) + C → A Carry → C	Carry	Complement and Add with Carry, Skip on Carry
CLRA		00	|0000|0000|	0 → A	None	Clear A
COMP		40	|0100|0000|	$\overline{A}$ → A	None	Ones complement of A to A
NOP		44	|0100|0100|	None	None	No Operation
RC		32	|0011|0010|	"0" → C	None	Reset C
SC		22	|0010|0010|	"1" → C	None	Set C

Instruction Set (Continued)

TABLE II. COP444L/445L Instruction Set (Continued)

Mnemonic	Operand	Hex Code	Machine Language Code (Binary)	Data Flow	Skip Conditions	Description
TRANSFER OF CONTROL INSTRUCTIONS						
XOR		02	0000 | 0010	A ⊕ RAM(B) → A	None	Exclusive-OR RAM with A
JID		FF	1111 | 1111	ROM ($PC_{10:8}$, A,M) → $PC_{7:0}$	None	Jump Indirect (Note 3)
JMP	a	6–	0110 | 0 | $a_{10:8}$	a → PC	None	Jump
		--	$a_{7:0}$			
JP	a	--	1 | $a_{6:0}$ (pages 2,3 only)	a → $PC_{6:0}$	None	Jump within Page (Note 4)
			or			
		--	11 | $a_{5:0}$ (all other pages)	a → $PC_{5:0}$		
JSRP	a	--	10 | $a_{5:0}$	PC + 1 → SA → SB → SC 00010 → $PC_{10:6}$ a → $PC_{5:0}$	None	Jump to Subroutine Page (Note 5)
JSR	a	6–	0110 | 1 | $a_{10:8}$	PC + 1 → SA → SB → SC a → PC	None	Jump to Subroutine
		--	$a_{7:0}$			
RET		48	0100 | 1000	SC → SB → SA → PC	None	Return from Subroutine
RETSK		49	0100 | 1001	SC → SB → SA → PC	Always Skip on Return	Return from Subroutine then Skip
MEMORY REFERENCE INSTRUCTIONS						
CAMQ		33	0011 | 0011	A → $Q_{7:4}$ RAM(B) → $Q_{3:0}$	None	Copy A, RAM to Q
		3C	0011 | 1100			
CQMA		33	0011 | 0011	$Q_{7:4}$ → RAM(B) $Q_{3:0}$ → A	None	Copy Q to RAM, A
		2C	0010 | 1100			
LD	r	–5	00 | r | 0101 (r = 0:3)	RAM(B) → A Br ⊕ r → Br	None	Load RAM into A Exclusive-OR Br with r
LDD	r,d	23	0010 | 0011	RAM(r,d) → A	None	Load A with RAM pointed to directly by r,d
		--	0 | r | d			
LQID		BF	1011 | 1111	ROM($PC_{10:8}$,A,M) → Q SB → SC	None	Load Q Indirect (Note 3)
RMB	0	4C	0100 | 1100	0 → $RAM(B)_0$	None	Reset RAM Bit
	1	45	0100 | 0101	0 → $RAM(B)_1$		
	2	42	0100 | 0010	0 → $RAM(B)_2$		
	3	43	0100 | 0011	0 → $RAM(B)_3$		
SMB	0	4D	0100 | 1101	1 → $RAM(B)_0$	None	Set RAM Bit
	1	47	0100 | 1101	1 → $RAM(B)_1$		
	2	46	0100 | 0110	1 → $RAM(B)_2$		
	3	4B	0100 | 1011	1 → $RAM(B)_3$		
STII	y	7–	0111 | y	y → RAM(B) Bd + 1 → Bd	None	Store Memory Immediate and Increment Bd
X	r	–6	00 | r | 0110 (r = 0:3)	RAM(B) ⟷ A Br ⊕ r → Br	None	Exchange RAM with A, Exclusive-OR Br with r
XAD	r,d	23	0010 | 0011	RAM(r,d) ⟷ A	None	Exchange A with RAM pointed to directly by r,d
		--	1 | r | d			

Instruction Set (Continued)

TABLE II. COP444L/445L Instruction Set (Continued)

Mnemonic	Operand	Hex Code	Machine Language Code (Binary)	Data Flow	Skip Conditions	Description
MEMORY REFERENCE INSTRUCTIONS (Continued)						
XDS	r	-7	|00|r|0111| (r = 0:3)	RAM(B) ⟷ A Bd − 1 → Bd Br ⊕ r → Br	Bd decrements past 0	Exchange RAM with A and Decrement Bd, Exclusive-OR Br with r
XIS	r	-4	|00|r|0100| (r = 0:3)	RAM(B) ⟷ A Bd + 1 → Bd Br ⊕ r → Br	Bd increments past 15	Exchange RAM with A and Increment Bd, Exclusive-OR Br with r
REGISTER REFERENCE INSTRUCTIONS						
CAB		50	|0101|0000|	A → Bd	None	Copy A to Bd
CBA		4E	|0100|1110|	Bd → A	None	Copy Bd to A
LBI	r,d	--	|00|r|(d - 1)| (r = 0:3; d = 0, 9:15)	r,d → B	Skip until not a LBI	Load B Immediate with r,d (Note 6)
			or			
		33	|0011|0011|			
		--	|1|r|d| any r, any d)			
LEI	y	33	|0001|0011|	y → EN	None	Load EN Immediate (Note 7)
		6-	|0110|y|			
XABR		12	|0001|0010|	A ⟷ Br (0 → A_3)	None	Exchange A with Br
TEST INSTRUCTIONS						
SKC		20	|0010|0000|		C = "1"	Skip if C is True
SKE		21	|0010|0001|		A = RAM(B)	Skip if A Equals RAM
SKGZ		33	|0011|0011|		$G_{3:0}$ = 0	Skip if G is Zero (all 4 bits)
		21	|0010|0001|			
SKGBZ		33	|0011|0011|	1st byte		Skip if G Bit is Zero
	0	01	|0000|0001|	2nd byte	G_0 = 0	
	1	11	|0001|0001|	2nd byte	G_1 = 0	
	2	03	|0000|0011|	2nd byte	G_2 = 0	
	3	13	|0001|0011|	2nd byte	G_3 = 0	
SKMBZ	0	01	|0000|0001|		$RAM(B)_0$ = 0	Skip if RAM Bit is Zero
	1	11	|0001|0001|		$RAM(B)_1$ = 0	
	2	03	|0000|0011|		$RAM(B)_2$ = 0	
	3	13	|0001|0011|		$RAM(B)_3$ = 0	
SKT		41	|0100|0001|		A time-base counter carry has occurred since last test	Skip on Timer (Note 3)
INPUT/OUTPUT INSTRUCTIONS						
ING		33	|0011|0011|	G → A	None	Input G Ports to A
		2A	|0010|1010|			
ININ		33	|0011|0011|	IN → A	None	Input IN Inputs to A (Note 2)
		28	|0010|1000|			
INIL		33	|0011|0011|	IL_3, CKO, "0", IL_0 → A	None	Input IL Latches to A (Note 3)
		29A	|0010|1001|			

Instruction Set (Continued)

TABLE II. COP444L/445L Instruction Set (Continued)

Mnemonic	Operand	Hex Code	Machine Language Code (Binary)	Data Flow	Skip Conditions	Description
INPUT/OUTPUT INSTRUCTIONS (Continued)						
INL		33	0011 | 0011	$L_{7:4} \rightarrow$ RAM(B)	None	Input L Ports to RAM, A
		2E	0010 | 1110	$L_{3:0} \rightarrow$ A		
OBD		33	0011 | 0011	Bd → D	None	Output Bd to D Outputs
		3E	0011 | 1110			
OGI	y	33	0011 | 0011	y → G	None	Output to G Ports Immediate
		5-	0101 | t			
OMG		33	0011 | 0011	RAM(B) → G	None	Output RAM to G Ports
		3A	0011 | 1010			
XAS		4F	0100 | 1111	A ⟷ SIO, C → SKL	None	Exchange A with SIO (Note 3)

Note 1: All subscripts for alphabetical symbols indicate bit numbers unless explicitly defined (e.g., Br and Bd are explicitly defined). Bits are numbered 0 to N where 0 signifies the least significant bit (low-order, right-most bit). For example, A_3 indicates the most significant (left-most) bit of the 4-bit A register.

Note 2: The ININ instruction is not available on the 24-pin COP445L or COP345L since these devices do not contain the IN inputs.

Note 3: For additional information on the operation of the XAS, JID, LQID, INIL, and SKT instructions, see below.

Note 4: The JP instruction allows a jump, while in subroutine pages 2 or 3, to any ROM location within the two-page boundary of pages 2 or 3. The JP instruction, otherwise, permits a jump to a ROM location within the current 64-word page. JP may not jump to the last word of a page.

Note 5: A JSRP transfers program control to subroutine page 2 (0010 is loaded into the upper 4 bits of P). A JSRP may not be used when in pages 2 or 3. JSRP may not jump to the last word in page 2.

Note 6: LBI is a single-byte instruction if d = 0, 9, 10, 11, 12, 13, 14 or 15. The machine code for the lower 4 bits equals the binary value of the "d" data *minus 1*, e.g., to load the lower four bits of B (Bd) with the value 9 (1001_2), the lower 4 bits of the LBI instruction equal 8 (1000_2). To load 0, the lower 4 bits of the LBI instruction should equal 15 (1111_2).

Note 7: Machine code for operand field y for LEI instruction should equal the binary value to be latched into EN, where a "1" or "0" in each bit of EN corresponds with the selection or deselection of a particular function associated with each bit. (See Functional Description, EN Register.)

Description of Selected Instructions

The following information is provided to assist the user in understanding the operation of several unique instructions and to provide notes useful to programmers in writing COP444L/445L programs.

SOFTWARE AND OPCODE DIFFERENCES IN THE COP444L INSTRUCTION SET

The COP444L is essentially a COP420L with a double RAM and ROM. Because of this increased memory space certain instructions have expanded capability in the COP444L. Note that there are no new instructions in the COP444L and that all instructions perform the same operations in the COP444L as they did in the COP420L. The expanded capability is merely to allow appropriate handling of the increased memory space. The affected instructions are:

JMP	a	(a = address)
JSR	a	(a = address)
LDD	r,d	(r,d = RAM address Br,Bd)
XAD	r,d	(r,d = RAM address Br,Bd)
LBI	r,d	(r,d = RAM address Br,Bd; only two byte form of the instruction affected)
XABR		

The JMP and JSR instructions are modified in that the address a may be anywhere within the 2048 words of ROM space. The opcodes are as follows:

JMP	0110 | 0 | a10:9:8	JSR	0110 | 1 | a10:9:8
	a7:0		a7:0

The LDD, XAD, and two byte LBI are modified so that they may address the entire RAM space. The opcodes are as follows:

LDD	0110 | 0011	XAD	0010 | 0011
	0 | r | d		1 | r | d
LBI	0011 | 0011		
	1 | r | d		

The XABR instruction change is transparent to the user. The opcode is not changed nor is the function of the instruction. The change is that values of 0 through 7 in A will address registers in the COP444L (i.e., the lower three bits of A become the Br value following the instruction). In the COP420L, the lower two bits of A became the Br value following an XABR instruction.

Note that those instructions which have an exclusive-or argument (LD, X, XIS, XDS) are not affected. The argument is still two bits of the opcode. This means that the exclusive-or aspect of these instructions works within blocks of four registers. It is not possible to toggle Br from a value between 0 and 3 to a value between 4 and 7 by means of these instructions.

Description of Selected Instructions (Continued)

There are no other software or opcode differences between the COP444L and the COP420L. Examination of the above changes indicates that the existing opcodes for those instructions have merely been extended. There is no fundamental change.

XAS INSTRUCTION

XAS (Exchange A with SIO) exchanges the 4-bit contents of the accumulator with the 4-bit contents of the SIO register. The contents of SIO will contain serial-in/serial-out shift register or binary counter data, depending on the value of the EN register. An XAS instruction will also affect the SK output. (See Functional Description, EN Register, above.) If SIO is selected as a shift register, an XAS instruction must be performed once every 4 instruction cycles to effect a continuous data stream.

JID INSTRUCTION

JID (Jump Indirect) is an indirect addressing instruction, transferring program control to a new ROM location pointed to indirectly by A and M. It loads the lower 8 bits of the ROM address register PC with the *contents* of ROM addressed by the 11-bit word, $PC_{10:8}$, A, M. PC_{10}, PC_9 and PC_8 are not affected by this instruction.

Note that JID requires 2 instruction cycles to execute.

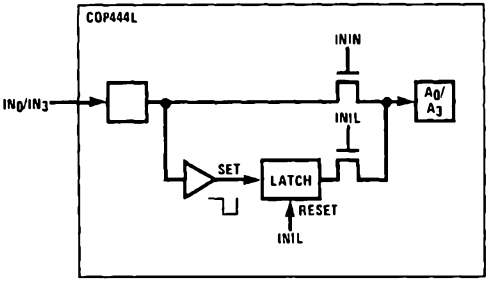
INIL INSTRUCTION

INIL (Input IL Latches to A) inputs 2 latches, IL_3 and IL_0 (see *Figure 7*) and CKO into A. The IL_3 and IL_0 latches are set if a low-going pulse ("1" to "0") has occurred or the IN_3 and IN_0 inputs since the last INIL instruction, provided the input pulse stays low for at least two instruction times. Execution of an INIL inputs IL_3 and IL_0 into A3 and A0 respectively, and resets these latches to allow them to respond to subsequent low-going pulses on the IN_3 and IN_0 lines. If CKO is mask programmed as a general purpose input, an INIL will input the state of CKO into A2. If CKO has not been so programmed, a "1" will be placed in A2. A "0" is always placed in A1 upon the execution of an INIL. The general purpose inputs IN_3–IN_0 are input to A upon execution of an ININ instruction. (See Table II, ININ instruction.) INIL is useful in recognizing pulses of short duration or pulses which occur too often to be read conveniently by an ININ instruction.

Note: IL latches are not cleared on reset; IL_3–IL_0 *not* input on 445L

LQID INSTRUCTION

LQID (Load Q Indirect) loads the 8-bit Q register with the contents of ROM pointed to by the 11-bit word PC_{10}, PC_9, PC_8 A, M. LQID can be used for table lookup or code conversion such as BCD to seven-segment. The LQID instruction "pushes" the stack (PC + 1 → SA → SB → SC) and replaces the least significant 8 bits of PC as follows: A → $PC_{7:4}$, RAM(B) → $PC_{3:0}$, leaving PC_{10}, PC_9 and PC_8 unchanged. The ROM data pointed to by the new address is fetched and loaded into the Q latches. Next, the stack is "popped" (SC → SB → SA → PC), restoring the saved value of PC to continue sequential program execution. Since LQID pushes SB → SC, the previous contents of SC are lost. Also, when LQID pops the stack, the previously pushed contents of SB are left in SC. The net result is that the contents of SB are placed in SC (SB → SC). Note that LQID takes two instruction cycle times to execute.



TL/DD/6928–21

FIGURE 7. INIL Hardware Implementation

SKT INSTRUCTION

The SKT (Skip On Timer) instruction tests the state of an internal 10-bit time-base counter. This counter divides the instruction cycle clock frequency by 1024 and provides a latched indication of counter overflow. The SKT instruction tests this latch, executing the next program instruction if the latch is not set. If the latch has been set since the previous test, the next program instruction is skipped and the latch is reset. The features associated with this instruction, therefore, allow the COP444L/445L to generate its own time-base for real-time processing rather than relying on an external input signal.

For example, using a 2.097 MHz crystal as the time-base to the clock generator, the instruction cycle clock frequency will be 65 kHz (crystal frequency ÷ 32) and the binary counter output pulse frequency will be 64 Hz. For time-of-day or similar real-time processing, the SKT instruction can call a routine which increments a "seconds" counter every 64 ticks.

Description of Selected Instructions (Continued)

INSTRUCTION SET NOTES

a. The first word of a COP444L/445L program (ROM address 0) must be a CLRA (Clear A) instruction.

b. Although skipped instructions are not executed, one instruction cycle time is devoted to skipping each byte of the skipped instruction. Thus all program paths except JID and LQID take the same number of cycle times whether instructions are skipped or executed. JID and LQID instructions take 2 cycles if executed and 1 cycle if skipped.

c. The ROM is organized into 32 pages of 64 words each. The Program Counter is an 11-bit binary counter, and will count through page boundaries. If a JP, JSRP, JID or LQID instruction is located in the last word of a page, the instruction operates as if it were in the next page. For example: a JP located in the last work of a page will jump to a location in the next page. Also, a LQID or JID located in the last word of page 3, 7, 11, 15, 19, 23 or 27 will access data in the next group of four pages.

Option List

The COP444L/445L mask-programmable options are assigned numbers which correspond with the COP*444L* pins.

The following is a list of COP444L options. When specifying a COP445L chip, Options 9, 10, 19, and 20 must all be set to zero. The options are programmed at the same time as the ROM pattern to provide the user with the hardware flexibility to interface to various I/O components using little or no external circuitry.

Option 1 = 0: Ground Pin—no options available

Option 2: CKO Output
- = 0: clock generator ouput to crystal/resonator (0 not allowable value if option 3 = 3)
- = 1: pin is RAM power supply (V_R) input
- = 2: general purpose input, load device to V_{CC}
- = 3: general purpose input, Hi-Z

Option 3: CKI Input
- = 0: oscillator input divided by 32 (2 MHz max.)
- = 1: oscillator input divided by 16 (1 MHz max.)
- = 2: oscillator input divided by 8 (500 kHz max.)
- = 3: single-pin RC controlled oscillator divided by 4
- = 4: oscillator input divided by 4 (Schmitt)

Option 4: $\overline{\text{RESET}}$ Input
- = 0: load device to V_{CC}
- = 1: Hi-Z input

Option 5: L_7 Driver
- = 0: Standard output
- = 1: Open-drain output
- = 2: High current LED direct segment drive output
- = 3: High current TRI-STATE push-pull output
- = 4: Low-current LED direct segment drive output
- = 5: Low-current TRI-STATE push-pull output

Option 6: L_6 Driver
same as Option 5

Option 7: L_5 Driver
same as Option 5

Option 8: L_4 Driver
same as Option 5

Option 9: IN_1 Input
- = 0: load device to V_{CC}
- = 1: Hi-Z input

Option 10: IN_2 Input
same as Option 9

Option 11: V_{CC} pin Operating Voltage

	COP44XL	COP34XL
= 0:	+4.5V to +6.3V	+4.5V to +5.5V

Option 12: L_3 Driver
same as Option 5

Option 13: L_2 Driver
same as Option 5

Option 14: L_1 Driver
same as Option 5

Option 15: L_0 Driver
same as Option 5

Option 16: SI Input
same as Option 9

Option List (Continued)

Option 17: SO Driver
- = 0: standard output
- = 1: open-drain output
- = 2: push-pull output

Option 18: SK Driver
same as Option 17

Option 19: IN_0 Input
same as Option 9

Option 20: IN_3 Input
same as Option 9

Option 21: G_0 I/O Port
- = 0: very-high current standard output
- = 1: very-high current open-drain output
- = 2: high current standard output
- = 3: high current open-drain output
- = 4: standard LSTTL output (fanout = 1)
- = 5: open-drain LSTTL output (fanout = 1)

Option 22: G_1 I/O Port
same as Option 21

Option 23: G_2 I/O Port
same as Option 21

Option 24: G_3 I/O Port
same as Option 21

Option 25: D_3 Output
same as Option 21

Option 26: D_2 Output
same as Option 21

Option 27: D_1 Output
same as Option 21

Option 28: D_0 Output
same as Option 21

Option 29: L Input Levels
- = 0: standard TTL input levels ("0" = 0.8V, "1" = 2.0V)
- = 1: higher voltage input levels ("0" = 1.2V, "1" = 3.6V)

Option 30: IN Input Levels
same as Option 29

Option 31: G Input Levels
same as Option 29

Option 32: SI Input Levels
same as Option 29

Option 33: RESET Input
- = 0: Schmitt trigger input levels
- = 1: standard TTL input levels
- = 2: higher voltage input levels

Option 34: CKO Input Levels (CKO = input; Option 2 = 2, 3)
same as Option 29

Option 35: COP Bonding
- = 0: COP444L (28-pin device)
- = 1: COP445L (24-pin device)
- = 2: both 28- and 24-pin versions

Option 36: Internal Initialization Logic
- = 0: normal operation
- = 1: no internal initialization logic

COP444L Option Table

The following option information is to be sent to National along with the EPROM.

	OPTION DATA	
OPTION 1	VALUE = 0	IS: GROUND PIN
OPTION 2	VALUE = _____	IS: CKO PIN
OPTION 3	VALUE = _____	IS: CKI PIN
OPTION 4	VALUE = _____	IS: RESET INPUT
OPTION 5	VALUE = _____	IS: L(7) DRIVER
OPTION 6	VALUE = _____	IS: L(6) DRIVER
OPTION 7	VALUE = _____	IS: L(5) DRIVER
OPTION 8	VALUE = _____	IS: L(4) DRIVER
OPTION 9	VALUE = _____	IS: IN1 INPUT
OPTION 10	VALUE = _____	IS: IN2 INPUT
OPTION 11	VALUE = 0	IS: VCC PIN
OPTION 12	VALUE = _____	IS: L(3) DRIVER
OPTION 13	VALUE = _____	IS: L(2) DRIVER
OPTION 14	VALUE = _____	IS: L(1) DRIVER
OPTION 15	VALUE = _____	IS: L(0) DRIVER
OPTION 16	VALUE = _____	IS: SI INPUT
OPTION 17	VALUE = _____	IS: SO DRIVER
OPTION 18	VALUE = _____	IS: SK DRIVER
OPTION 19	VALUE = _____	IS: IN0 INPUT
OPTION 20	VALUE = _____	IS: IN3 INPUT

	OPTION DATA	
OPTION 21	VALUE = _____	IS: G0 I/O PORT
OPTION 22	VALUE = _____	IS: G1 I/O PORT
OPTION 23	VALUE = _____	IS: G2 I/O PORT
OPTION 24	VALUE = _____	IS: G3 I/O PORT
OPTION 25	VALUE = _____	IS: D3 OUTPUT
OPTION 26	VALUE = _____	IS: D2 OUTPUT
OPTION 27	VALUE = _____	IS: D1 OUTPUT
OPTION 28	VALUE = _____	IS: D0 OUTPUT
OPTION 29	VALUE = _____	IS: L INPUT LEVELS
OPTION 30	VALUE = _____	IS: IN INPUT LEVELS
OPTION 31	VALUE = _____	IS: G INPUT LEVELS
OPTION 32	VALUE = _____	IS: SI INPUT LEVELS
OPTION 33	VALUE = _____	IS: RESET INPUT
OPTION 34	VALUE = _____	IS: CKO INPUT LEVELS
OPTION 35	VALUE = _____	IS: COP BONDING
OPTION 36	VALUE = _____	IS: INTERNAL INITIALIZATION LOGIC

Typical Applications

TEST MODE (NON-STANDARD OPERATION)

The SO output has been configured to provide for standard test procedures for the custom-programmed COP444L. With SO forced to logic "1", two test modes are provided, depending upon the value of SI:

a. RAM and Internal Logic Test Mode (SI = 1)

b. ROM Test Mode (SI = 0)

These special test modes should not be employed by the user; they are intended for manufacturing test only.

APPLICATION # 1: COP444L GENERAL CONTROLLER

Figure 8 shows an interconnect diagram for a COP444L used as a general controller. Operation of the system is as follows:

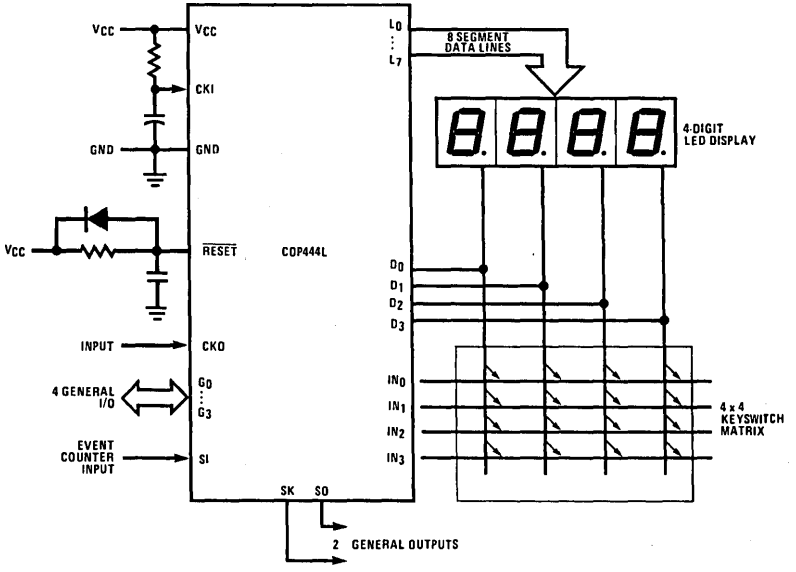
1. The L_7–L_0 outputs are configured as LED Direct Drive outputs, allowing direct connection to the segments of the display
2. The D_3–D_0 outputs drive the digits of the multiplexed display directly and scan the columns of the 4 x 4 keyboard matrix.
3. The IN_3–IN_0 inputs are used to input the 4 rows of the keyboard matrix. Reading the IN lines in conjunction with the current value of the D outputs allows detection, debouncing, and decoding of any one of the 16 keyswitches.
4. CKI is configured as a single-pin oscillator input allowing system timing to be controlled by a single-pin RC network. CKO is therefore available for use as a general-purpose input.
5. SI is selected as the input to a binary counter input. With SIO used as a binary counter, SO and SK can be used as general purpose outputs.
6. The 4 bidirectional G I/O ports (G_3–G_0) are available for use as required by the user's application.
7. Normal reset operation is selected.

COP444L EVALUATION (See COP Note 4)

The 444L-EVAL is a pre-programmed COP444L, containing several routines which facilitate user familiarization and evaluation of the COP444L operating characteristics. It may be used as an up/down counter or timer, interfacing to any combination of (1) an LED digit or lamps, (2) 4-digit LED Display Controller, (3) a 4-digit VF Display Controller, and/or (4) a 4-digit LCD Display Controller. Alternatively, it may be used as a simple music synthesizer.

SAMPLE CIRCUITS

1. By making only the oscillator, power supply and "L7" connections, *(Figure 9)* an approximate 1 Hz square wave will be produced at output "D1." This output may be observed with an oscilloscope, or connected to additional TTL or CMOS circuitry.
2. By making the indicated connections to a small LED digit (NSA1541A, NSA1166, or equiv.—larger digits will be proportionately dimmer), the counter actions may be observed. Place the "up/down" switch in the "up" (open) position and apply a TTL-compatible signal at the "counter-input." Placing the "up/down" switch in the "down" (closed) position causes the count to decrement on each high-to-low input transition.
3. All 4 digits of the counter may be displayed by connecting a standard display controller (COP472 for LCD, MM5450 for LED) as shown in *Figure 9*.



TL/DD/6928-22

FIGURE 8. COP444L Keyboard/Display Interface

Typical Applications (Continued)

Any combination of the single LED digit and display controllers may be used simultaneously, and will display the same data.

4. The simple counter described above becomes a timer when the 1 Hz output is connected to the "counter input." Up or down counting may be used with input frequencies up to 1 kHz. Improved timing accuracies may be obtained by subsituting the 2.097 MHz crystal oscillator circuit of *Figure 4a* for the RC network shown in *Figure 9*, or by connecting a more stable external frequency to the "counter input" in place of the 1 Hz signal.
5. An "entertaining" use of the 444L-EVAL is as a simple music synthesizer (or electronic organ). By attaching a simple switch matrix (or keyboard), a speaker or piezo-ceramic transducer, and grounding "L7", the user can play "music" *(Figure 10)*. Three modes of operation are available: Play a note, play one of four stored tunes, or record a tune for subsequent replay.

   a. *Play A Note*

   Twelve keys, representing the 12 notes in one octave, are labeled "C" through "B"; depressing a key causes a square wave of the corresponding frequency to be outputted to the speaker. Depressing "LShift" or "UShift" causes the next note to be shifted to the next lower octave (one-half frequency) or the next upper octave (double frequency), respectively.

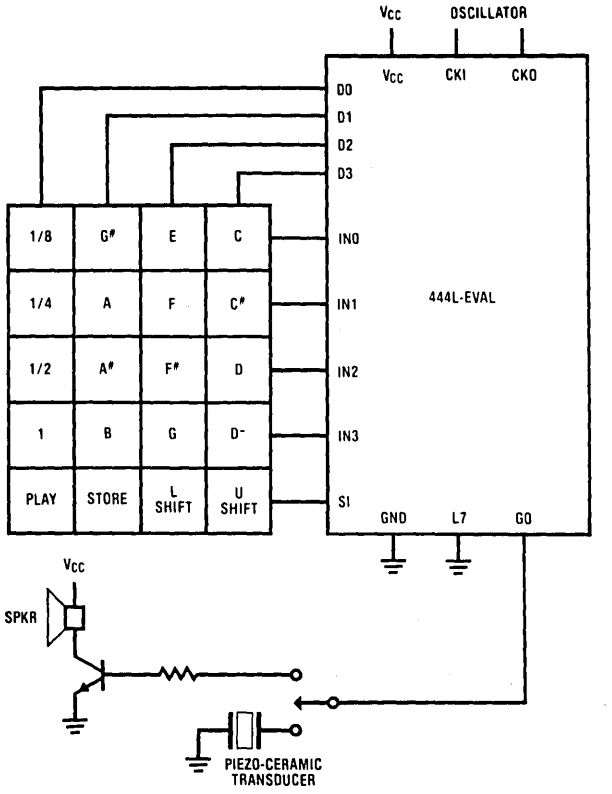
   b. *Play Stored Tune*

   Depressing "Play" followed by "⅛", "¼", "½", or "1" will cause one of 4 stored tunes to be played.

   c. *Record Tune*

   Any combination of notes and rests up to a total of 48 may be stored in RAM for later replay. To store a note, press the appropriate note key, followed by the duration of the note (⅛-note, ¼-note, ½-note, whole (1)-note, followed by "Store"; a rest is stored by selecting the duration and pressing "Store." When the tune is complete, press "Play" followed by "Store"; the tune will be played for immediate audition. Subsequent depression of "Play" and "Store" will replay the last stored tune.

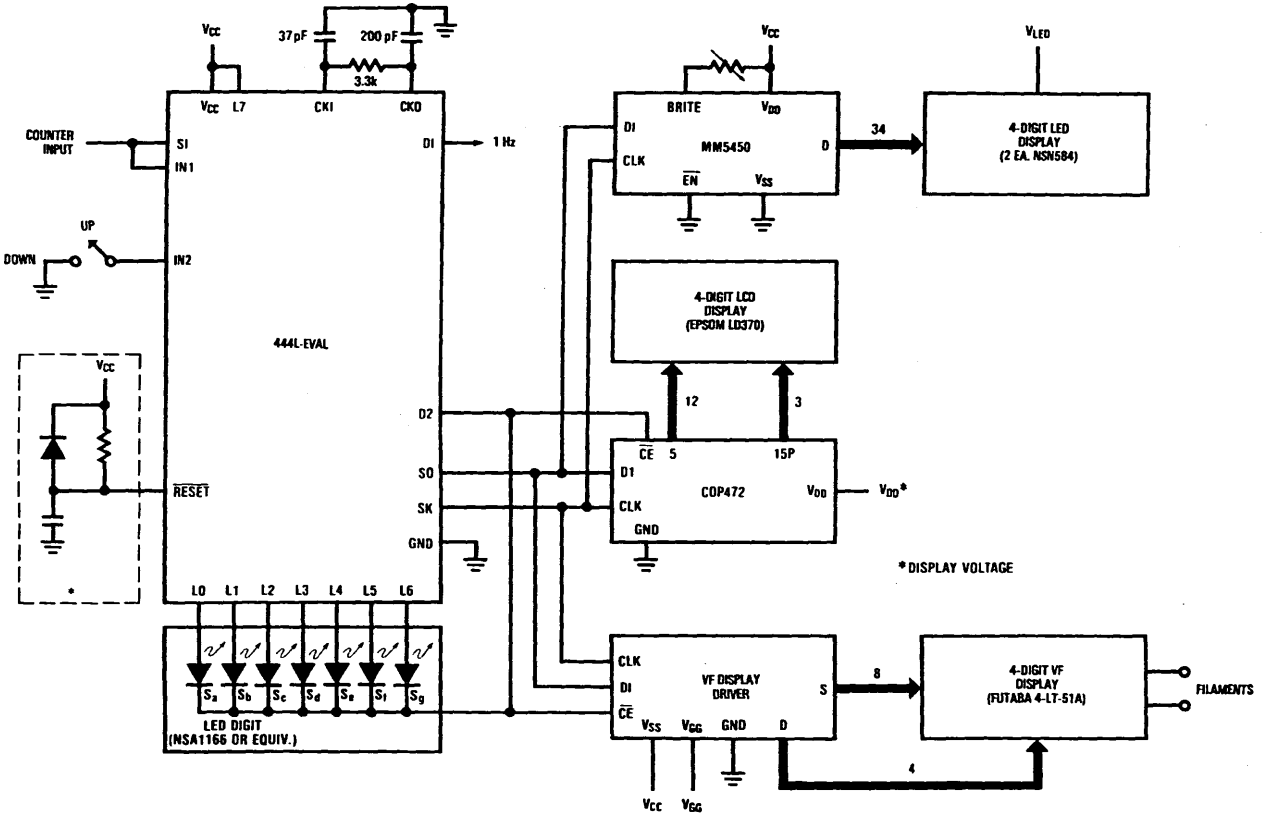
Note: The accuracy of the tones produced is a function of the oscillator accuracy and stability; the crystal oscillator is recommended.



TL/DD/6928-23

FIGURE 9. Counter/Timer

Typical Applications (Continued)



* See "Initialization"

FIGURE 10. Music Synthesizer