INTERSIL

ICM7045/A CMOS Precision Decade Timers

FEATURES

- **Total Integration: Includes oscillator, divider, decoder driver on chip**
- **Wide operating supply range: 2.5V ≤ V+ ≤ 4.5V**
- **Low operating power consumption: 0.9 mW @ 3.6V supply with display off**
- **High output current drive: 18 mA peak current per segment with 12.5% duty cycle.**
- **Leading zero suppression: timer stopwatch applications**
- **Fractional second suppression: 24-hour clock application**
- **Short duration short circuit protection on all inputs and outputs at 3.6V supply**

ICM7045

- **Versatility of applications: precision timer, 4 mode stopwatch, 24-hour clock**
- **Uses 6.5536 MHz quartz crystal for high accuracy**

ICM7045/A

- **May Be Used to Count**
  –Seconds (1.310772 MHz crystal)
  –Minutes (2.184533 MHz crystal)
  –Hours (3.640889 MHz crystal)

GENERAL DESCRIPTION

The ICM7045/A are fully integrated precision decade timers fabricated using Intersil's low voltage metal gate C-MOS technology. The oscillator, frequency divider, multiplexer, decoder, segment and digit output buffers are all included on-chip. The circuits are designed to interface directly with fully multiplexed 8-digit 7-segment common cathode LED displays. The normal supply voltage is 3.6V, equivalent to a stack of three nickel cadmium batteries.

The ICM7045

The ICM7045 divides the oscillator frequency in sixteen binary stages to a frequency of 100 Hz; some of these intermediate outputs are used to generate the multiplex waveforms at a 12.5% duty cycle/800 Hz rate. The 100 Hz signal is then processed in the counters and multiplexed in the decoders.

This circuit is designed for use as a digital timer, 4-function stopwatch and 24 hour clock; the only external components required are the display, batteries, 6.5536 MHz crystal, turning capacitor and 4 switches.

The ICM7045A

The main difference between the 7045 and 7045A is that the divide by sixty counters of the 7045 are replaced by decade counters in the 7045A. Thus seconds, minutes or hours may be counted in a decade fashion, depending on the choice of oscillator frequency.

The two other differences are: the oscillator is divided by 2^{17} in the 7045A, and CATH 8 (LSD) is not used.

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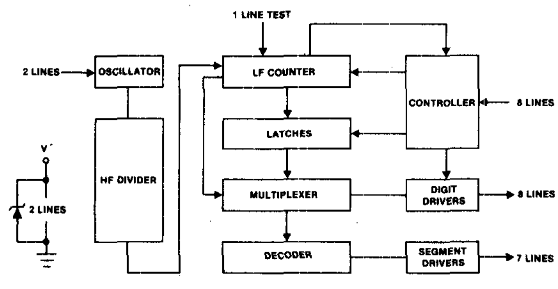
BLOCK DIAGRAM



ZENOR DIODE HAS TYPICAL BREAKDOWN VOLTAGE OF 6.5V.

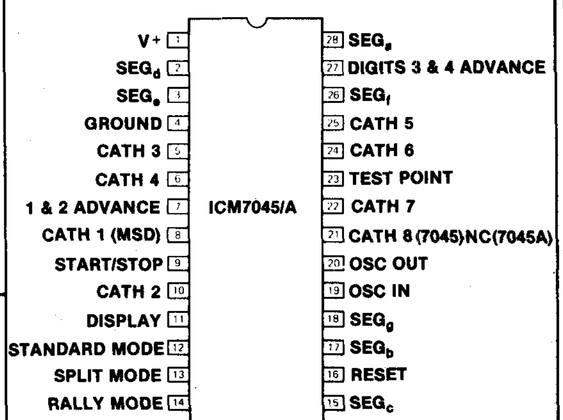
ORDERING INFORMATION

ICM7045 A I DI

- DI — Package: 28 Pin Plastic DIP
- I — Temperature Range: I = Industrial −20°C to +85°C
- A — Option
- ICM7045 — Type

Order Dice by Following Part Number — ICM7045/D, ICM7045A/D

PIN CONFIGURATION (outline dwg DI)



ABSOLUTE MAXIMUM RATINGS

Power Dissipation (1) 1W
Supply Voltage .... +5.5V
Input Voltage .... Equal to, but never in excess of the supply voltages
Output Voltage .... Equal to, but never in excess of the supply voltages
Digit Drive Output Current 150mA/digit
Storage Temperatures .... −55°C to +125°C
Operating Temperatures .... −20°C to +85°C
Lead Temperature (Soldering, 10 sec) .... 300°C

NOTE: Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 1: This value of power dissipation refers to that of the package and will not be obtained under normal operating conditions.

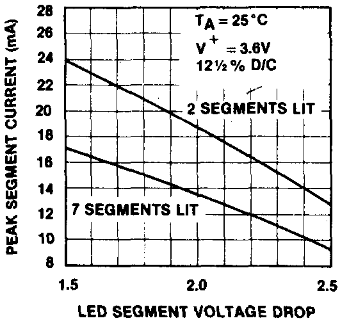
TYPICAL OPERATING CHARACTERISTICS

TEST CONDITIONS: V+ = 3.6V, $T_A = 25°C$ Parameters listed are absolute value

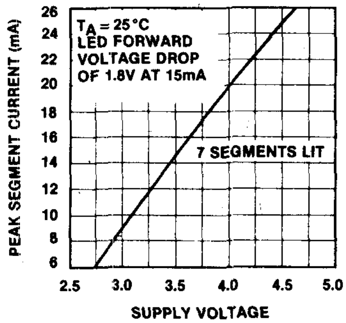
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current	I+	Display Off		180	2000	μA
		7 Segments Lit $V_F = 1.8V$	70	105		mA
		2 Segments Lit $V_F = 1.8V$	28	42		mA
Operating Voltage	V^+	$-20°C < T_A < 85°C$	2.5		4.5	V
Segment Current Drive	I_{SEG}	7 Segments I.T., $V_F = 1.8V$, 12.5% Duty Cycle				
Instantaneous			10	15		mA
Average			1.25	1.825		mA
Segment Current Drive		2 Segments Lit, $V_F = 1.8V$ 12.5% Duty Cycle				
Instantaneous			14	21		mA
Average			1.75	2.625		mA
Min. Switch Actuation Current, Any Switch	I_{SW}		50			μA
Digit Driver Leakage Current	I_{DLK}				200	μA
Segment Driver Leakage Current	I_{SLK}				200	μA
Typical Oscillator Stability	f_{STAB}	$3V \leq V^+ \leq 4V$, $C_{TUNING} = 15pF$		1.0		ppm
Oscillator Start Up Time	t_{start}	$V^+ = 3.6V$			0.1	sec
		$V^+ = 2.5V$			1.0	sec
Oscillator Input Capacitance	C_{IN}			17		pF

TYPICAL PERFORMANCE CURVES

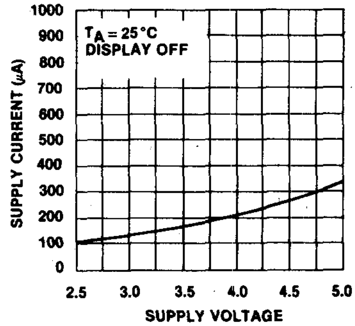
PEAK SEGMENT CURRENT DRIVE VS. LED SEGMENT VOLTAGE DROP



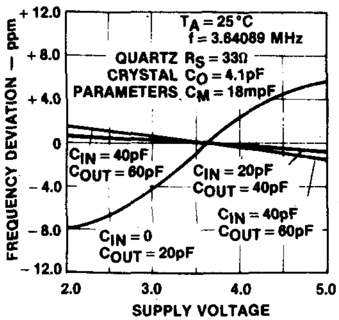
PEAK SEGMENT CURRENT VS. SUPPLY VOLTAGE

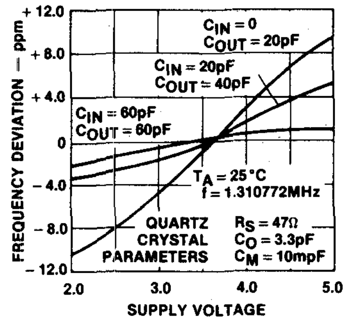


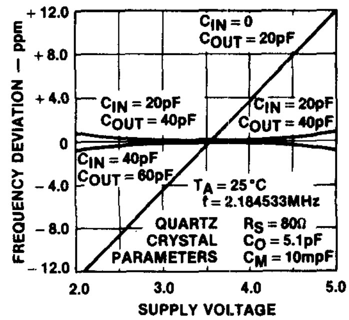
SUPPLY CURRENT VS. SUPPLY VOLTAGE



OSCILLATOR STABILITY VS. SUPPLY VOLTAGE FOR 3 DIFFERENT QUARTZ CRYSTALS (ICM7045A)

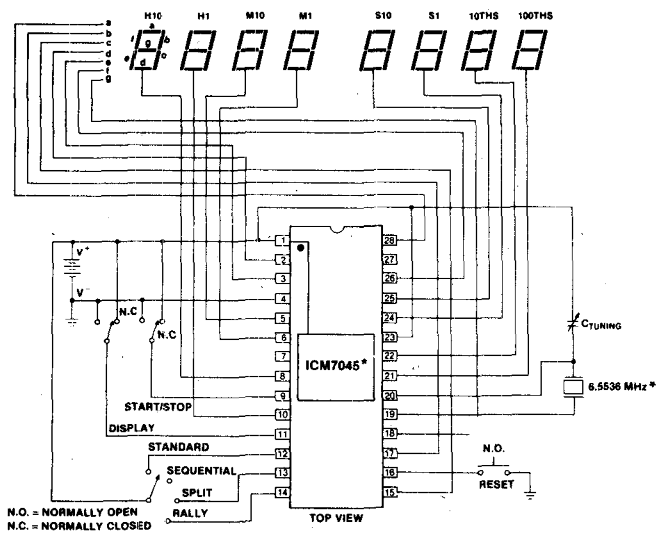






ICM7045

Quartz Crystal Parameters
f = 6.5536 MHz
R_s = 40Ω
C_1 = 15mpF
C_O = 3.5pF



*Shown for ICM7045. The same circuit may be used with the 7045A if a different crystal frequency is chosen.

NOTE: Specify quartz crystal to have nominal frequency value when tuned by a total parallel capacitance value of 12 pF or less.

Figure 1: Four Stopwatch Modes

FUNCTIONAL OPERATION

STOPWATCH/TIMER OPERATION

The control inputs used in the complete stopwatch application are: (refer to fig. 1)

START/STOP	RESET	SPLIT
DISPLAY	STANDARD	RALLY

START/STOP and DISPLAY are designed for connection to single pole double throw switches to insure operation free of contact bounce.

The switch connected to RESET can be normally open single pole single throw. STANDARD, SPLIT and RALLY are control points with internal pull down resistors to V^-. These are designed to be connected to a rotary function switch which will connect no more than one of these points to V^+. If STANDARD (SPLIT, RALLY) is connected to $V+$ the stopwatch is said to be in the STANDARD (SPLIT, RALLY) mode. If all three are left open, the stopwatch is in the SEQUENTIAL mode.

RESET FUNCTION

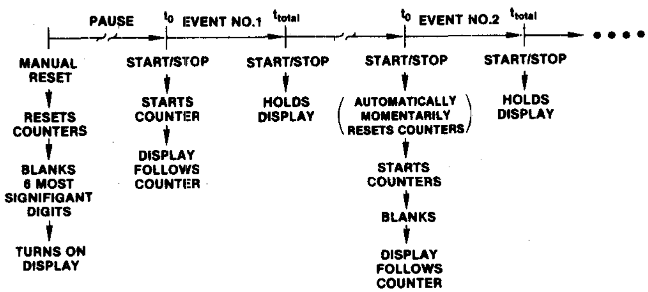
When the stopwatch is turned on, the RESET will normally be activated. This puts the stopwatch in a ready condition by:

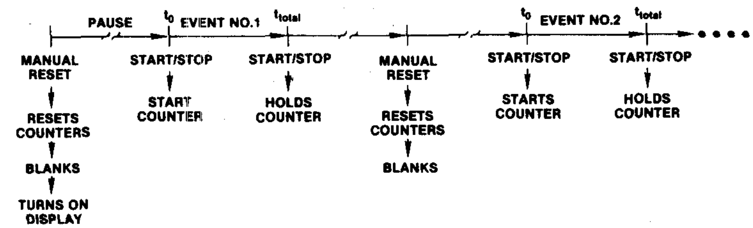
1. Resetting all circuitry
2. Blanking seconds, minutes, hours
3. Showing 00 in the two least significant digits. (7045; least significant digit 7045A)
4. Turning on the display if it was previously turned off

The display of just two zeros in the two least significant digits (7045; least significant digit 7045A) gives the complete assurance that the stopwatch is "ready to go."

STANDARD MODE

In the STANDARD mode, after a reset has taken place, START/STOP is activated at time t_0. The clock and display are moving simultaneously. A second activation of START/STOP stops the clock and holds the display at time t_{total}. This completes an event. For timing a second event there are two options. One is to activate START/STOP at the start of the second event. This will momentarily reset the counter and display so that the timing of the second event proceeds from zero. Another activation of START/STOP stops the counter and display at time t_{total} to end the second event. The other option is to activate RESET after the first event is over. Then the second event proceeeds similarly to the first event. As is clear from this description, RESET can be used at any time to reset the stopwatch, including when a timing is in progress. The DISPLAY input can be activated to turn the display off and on. If the display is off when RESET is activated, it will reset and turn on. Turning off the display for timing long events will result in a very substantial power saving.



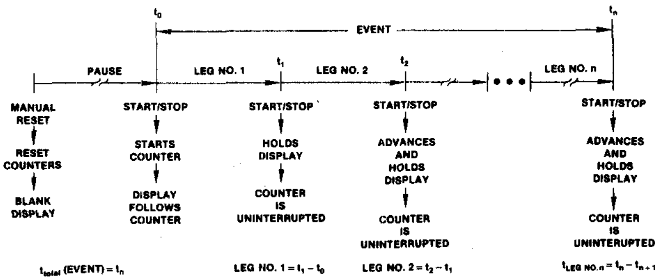


SEQUENTIAL MODE

The sequential mode of the stopwatch is designed for timing events consisting of more than one leg (such as relays, multilap races, etc.). After the initial reset the START/STOP is activated at t_0 to start the event. A second activation of START/STOP at time t_1 stops the display and allows t_1 to be read out, while the clock resets and starts counting again instantaneously. At time t_2 an activation of START/STOP enters t_2 (the time of leg 2) into the display. This sequence can continue indefinitely. Assuming the total event has n legs, the total elapsed time is then equal to the sum of the n times read out:

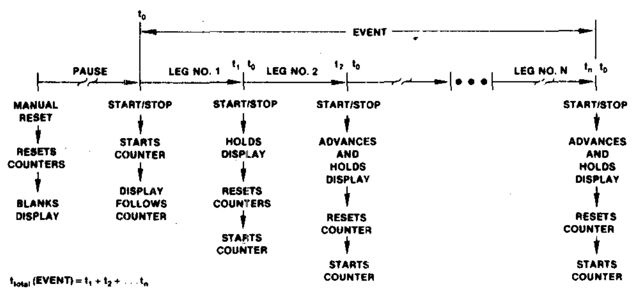
$$t_{total} = t_1 + t_2 \ldots + t_n$$

If it is desired to see the moving clock after a time has been recorded, the DISPLAY switch can be activated to release the display hold and catch up with the moving clock. The display cannot be turned off in the sequential mode. RESET can be activated at any time to reset clock and display.



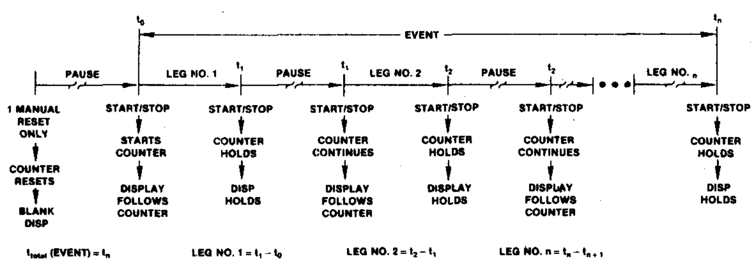
SPLIT MODE

The split mode is another mode for timing multileg events. In contrast to the sequential mode, the timing in the split mode is cumulative. From a reset condition, the START/STOP switch is activated at t_0 to start the counter and display running. A second activation at t_1 stops the display and allows t_1 to be read out while counter continues timing. A third activation at t_2 advances the display with the total elapsed time from t_0 to t_2 showing. Finally, at time t_n the total elapsed time of the event is entered in the display. The time of one leg of the event can be obtained by subtraction. The display can be synchronized to the counter (catch-up function) at any time by activating the display switch. To reset the timer, activate reset. The display cannot be turned off in the SPLIT mode.



RALLY MODE

The rally mode is designed for timing of events with interruptions. Consider an n leg event where the legs may be separated by intervals which should not be timed. The rally mode starts with a RESET. At time t_0 the stopwatch is started by activating START/STOP. After this point the RESET function is disabled to prevent accidental resets during long timing intervals. At time t_1 a START/STOP pulse stops counter and display. From here on each leg time is added to the total by a START/STOP pulse at the beginning of the leg and at the end. The individual leg times are determined by subtraction. The display can be turned on and off with the display switch.



CLOCK OPERATION

The control inputs used in a possible 24-hour clock configuration are (refer to fig. 2):

START/STOP
MINUTES ADVANCE
HOURS ADVANCE
RALLY

START/STOP, MINUTES ADVANCE and HOURS ADVANCE are designed for connection to single pole double throw switches; this assures contact bounce elimination on these inputs. To avoid an additional switch for the DISPLAY input, the RALLY input should be connected to V+ through a 20k resistor and to V− through a 0.01μF capacitor. These components insure that the display is on when power is applied to the circuit. The most convenient setting procedure is:

1. If clock is not running when power is applied activate START/STOP switch.
2. Depress MINUTES ADVANCE switch to obtain correct minutes setting, one minute count per activation.
3. Depress HOURS ADVANCE switch to obtain correct HOURS setting, one hour count per activation.

It is possible to set the clock more accurately or to correct small time errors by using START/STOP in combination with MINUTES ADVANCE. If the clock is, for instance, 20 seconds slow, activate the MINUTES ADVANCE once, then activate the START/STOP, wait 40 seconds and activate the START/STOP again. If the clock is 20 seconds fast, the START/STOP switch should be activated to stop the clock, then after 20 seconds activated again to restart the clock. Other clock configurations are possible (see Application Notes).

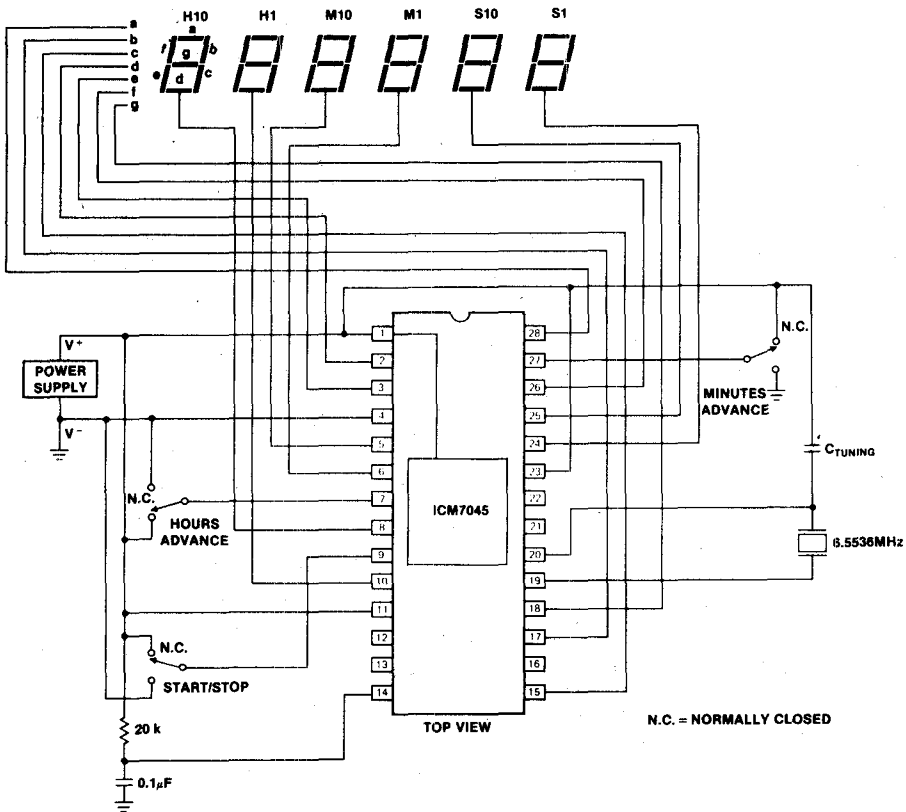


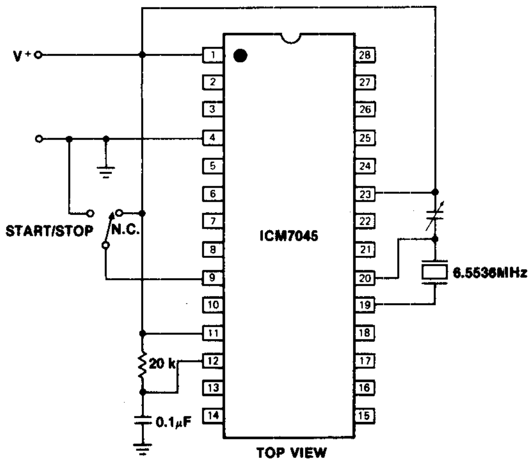
Figure 2: Clock Mode

APPLICATION NOTES

The ICM7045/A have been designed with versatility of applications in the digital timer/stopwatch/24-hour clock field as the major objective. The simplicity of operating modes allow for an extremely practical, easy to use stopwatch, at the same time permit the design of a variety of simple lapse timer, stopwatch and clock circuits; a few of these will be shown and discussed briefly here. Note that circuits shown are identical for 7045 and 7045A. When using the 7045A, a different crystal frequency must be chosen.

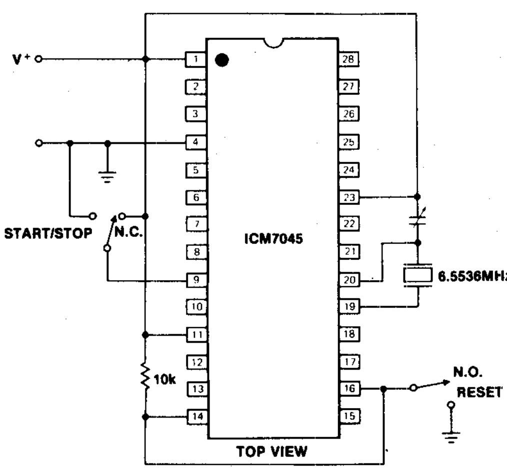
TIMER CIRCUIT I

This simple circuit (display connections not shown) allows interval timing up to 24 hours with a resolution of 0.01 second. Each interval is timed by one start and one stop pulse on the start/stop line. The start pulse for the next interval to be timed automatically resets the timer. Leading zero suppression is automatic.



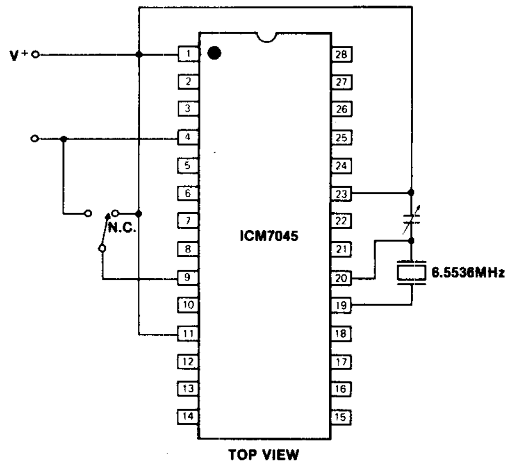
TIMER CIRCUIT II

This circuit allows cumulative timing of intervals. Each interval is timed by one start and one stop pulse on the start/stop line. Each subsequent interval timed adds to the total line displayed. The reset switch allows the timer to be reset to zero to start another sequence of intervals. Note that the time between the end of one interval and the start of the reset is not recorded nor added to the total.



TIMER CIRCUIT III

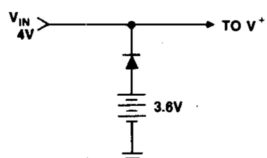
This circuit allows interval timing with a single pulse on the start/stop line. Each pulse enters the time elapsed since the previous pulse into the display, resets the timer and starts the timer for the next interval.



CLOCK CIRCUIT I

The standard clock circuit is shown and described in fig. 2. The clock accuracy with a stable voltage supply will depend mostly on the temperature and aging characteristics of the crystal.

The power supply can be modified to give battery standby power.

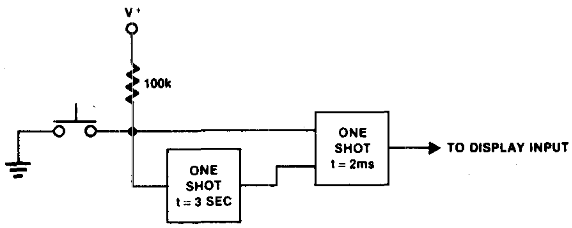


The standby circuit should be designed to provide the specified minimum voltage to the ICM7045.

OTHER CLOCK CIRCUITS

The basic clock circuit can be modified for various special applications. If it is desired to turn the display on and off, then connect the display input to an additional SPDT switch, while omitting the capacitor/resistor combination on the STANDARD Input.

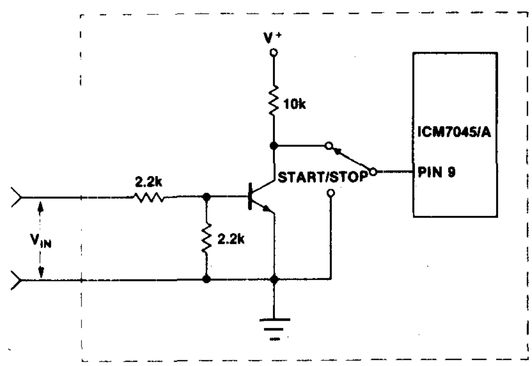
This input can then be wired directly to V^+. This 24-hour clock version might be applicable to vehicles, boats, etc. where a battery is available to supply the display off clock current, while the display can be turned on with the ignition. Another possible configuration would connect a special circuit to the DISPLAY input which generates a double pulse about 3 seconds apart:



This means depressing the switch will turn on the clock's display for 3 seconds. This allows design of a battery operated "on demand" digital 24-clock.

STOPWATCH EXTERNAL SYNC CIRCUIT

If the stopwatch is connected as shown in fig.1, a few additional components will allow external synchronization of the stopwatch in any mode:



NOTE: Be sure to minimize the distance between the transistor and the ICM7045 to prevent noise from being generated along this connection. *Noise spikes absolutely must not exceed the supply voltages.*

The external sync signal source must supply a positive pulse to activate the START/STOP input. The minimum voltage of this pulse is about 1.2V in the circuit as shown, but the triggering level can be changed by modifying the input resistor ratio. The output impedance of the external sync signal source should be no greater than 4k ohms.

THE ICM7045A

The ICM7045A will count to a total of 2399999. The next count will show 0000000. On appliction of RESET the display will show 0 on the least significant digit; all other digits will be blanked. Leading zero suppression blanking is performed on pairs of digits. For example, 9 will show as 9, 10 will show as 010, 999 will show as 999, 1000 will show as 01000 and so forth.

The oscillator frequency alone determines whether the timer is to be used for second, minute or hour counting.

'SECONDS' TIMER Use a 1.31072MHz quartz crystal

DIGIT #	1	2	3	4	5	6	7
	100K Secs	10K Secs	1K Secs	100 Secs	10 Secs	Secs	Sec ÷ 10

'MINUTES' TIMER Use a 2.184533MHz quartz crystal

DIGIT #	1	2	3	4	5	6	7
	1K Mins	100 Mins	10 Mins	Mins	Min ÷ 10	Min ÷ 100	Min ÷ 1000

'HOURS' TIMER Use a 3.640889MHz quartz crystal

DIGIT #	1	2	3	4	5	6	7
	10 Hrs	Hrs	Hrs ÷ 10	Hrs ÷ 100	Hrs ÷ 1,000	Hrs ÷ 10,000	Hrs ÷ 100,000

OSCILLATOR CONSIDERATIONS

The oscillator is a high gain complementary MOS inverter with on-chip feedback resistors and an on-chip fixed input capacitor of 22pF. For the 6.5536 MHz crystal needed for normal timing, it is suggested that the nominal load capacitance be kept under 12pF to keep total loading on the oscillator to a reasonable level. The actual trimmer range and the nominal load capacitance needed will have to be determined from the total stray capacitance of the particular circuit (including ICM7045 with package, PC board, etc.) and the tuning tolerance of the chosen crystal.

The series resistance of the crystal should also be kept to a low value (typically less than 50 ohms) to achieve adequate low voltage operation.

Oscillator tune up can be most easily performed using a pull-up resistor of 10k ohms on the fractional seconds digit, using period average tune for 1.25ms (800Hz).

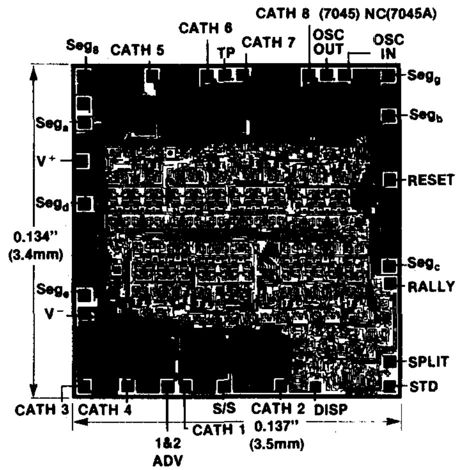
The oscillator of the ICM7045A is identical to that of the ICM7045, with the exception of the crystal frequency and load capacitance. Using similar value tuning capacitances with the lower frequency crystals (1.31077HHz, 2.184MHz 3.64089MHz) the stability of the oscillator is significantly degraded. It is therefore recommended that the tuning capacitances be increased to a nominal total of 40pF at both the oscillator input and output. Since there is an on chip input capacitance of 20-22pF the additional external input capacitance should be approximately 20pF.

The ICM7045A is guaranteed to operate over the supply voltage range of 2.5 to 4.5V using nominal input and output tuning capacitances of 40pF and with crystals having the following characteristics:

f = 1.310772MHz
2.184533MHz
3.64089MHz

$R_S \leq 100\Omega$ (150Ω for 1.310772MHz)
C_M – 10-20mpF
$C_O \leq 6$pF
C_L = 20pF (parallel resonance mode)

CHIP TOPOGRAPHY



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