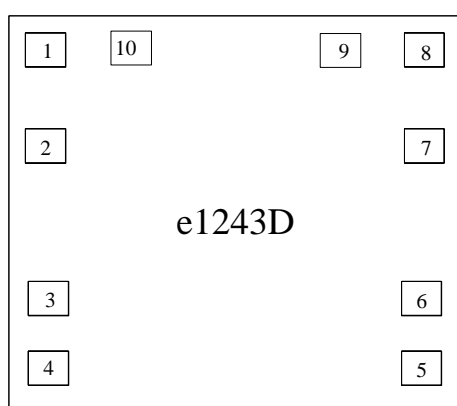


## 32-kHz Watch CMOS IC with Motor Regulation (3.0 V)

### Features

- 32-kHz oscillator
- 2.2 V to 3.6 V operating-voltage range
- 120 nA typical current consumption
- Motor regulation for minimum current consumption (MCAP)
- Voltage regulator
- Amplitude controlled oscillator
- Integrated capacitors, mask-selectable
- Mask options for pad designation and adaptation to the motor
- Low resistance outputs for bipolar stepping motor
- Motor fast-test function

### Pad Configuration



Pad size = 112  $\mu$ m  $\times$  112  $\mu$ m

13400

Figure 1. Chip size: 1.75 mm x 1.18 mm

### General Description

The e1243D is an integrated circuit in CMOS Silicon-Gate Technology for analog watches. It consists of a 32-kHz oscillator, frequency dividers down to 1/2 Hz, output pulse formers and push-pull motor drivers. Capacitors are provided (selectable mask option) for tuning the crystal. Low current consumption and high oscillator stability are achieved by an on-chip voltage regulator.

Pin	Symbol	Function
1 to 6, 8	V <sub>SS</sub>	Negative supply voltage
1 to 5, 8	V <sub>DD</sub>	Positive supply voltage
1 to 4	OSCIN/ OSCOUT	Oscillator input/ output
7 5 and 6	MOT 1 MOT 2	Motor drive outputs
1 to 5, 8	RESET	Reset input
1 to 5, 8	M_TEST	Motor test input

### Absolute Maximum Ratings

Parameters	Symbol	Value	Unit
Supply voltage	V <sub>DD</sub>	-0.3 to +5 V	V
Input voltage range, all inputs	V <sub>IN</sub>	(V <sub>SS</sub> - 0.3 V) $\leq$ V <sub>IN</sub> , $\leq$ (V <sub>DD</sub> + 0.3 V)	V
Output short-circuit duration		indefinite	
Power dissipation (DIL package)	P <sub>tot</sub>	125 mW	mW
Operating ambient temperature range	T <sub>amb</sub>	-20 to +70	°C
Storage temperature range	T <sub>stg</sub>	-40 to +125	°C
Lead temperature during soldering at 2 mm distance, 10 seconds	T <sub>sld</sub>	260	°C

Absolute maximum ratings define parameter limits which, if exceeded, may permanently change or damage the device.

All inputs and outputs in TEMIC Semiconductors' circuits are protected against electrostatic discharges.

However, precautions to minimize the build-up of electrostatic charges during handling are recommended.

This circuit is protected against supply voltage reversal for typically 5 minutes.

## Functional Description

### Voltage Regulator

An integrated voltage regulator provides the oscillator and the leading five divider stages with a well controlled positive supply voltage  $V_{REG}$ . Due to this reduced supply voltage, the frequency stability of the oscillator versus supply voltage variations is significantly improved and the current consumption of the circuit is minimized.

### Oscillator

For generation of the 32768-Hz clock frequency, an amplitude controlled oscillator is used. The amplitude of the oscillator input signal is held constant independent of external load conditions (i.e., trimmer capacitance and quartz characteristics), minimizing the current consumption of the oscillator. For typical supply current versus  $C_{TRIM}$  and quartz  $R_S$  variations see figure 3.

A total capacitance of 22 pF is integrated, which can be selected for  $C_{SCOUT}$  in 1 pF increments by metal mask options.

A trimming capacitor (chip capacitor) for frequency adjustment has to be connected between  $OSCIN$  and  $V_{SS}$ .

### Motor Drive Output

The e1243D contains two push-pull output buffers for driving bipolar stepper motors. During a motor pulse, the n-channel device of one buffer and the p-channel device of the other buffer is activated. Between two pulses, the p-channel devices of both buffers are active (see figure 4). Motor period  $t_M$  is 2 s.

### Reset

Connecting the RESET input to  $V_{DD}$  for at least 31.2 ms resets the frequency divider, thus disabling further motor pulses. Motor pulses in progress when the reset function is applied will be completed. After releasing the RESET pad from  $V_{DD}$ , the next motor pulse appears with a delay of one half motor period (1 s) on the drive output opposed to the former (see figure 5).

#### 4.2.7 Motor Test

Connecting  $M\_TEST$  to  $V_{DD}$  for at least 31.2 ms changes the motor period from 2 s to either 62.5 ms or 125 ms ( $t_{MT}$  mask options), while the timing of the motor current regulation remains unchanged (see figure 4).

### MCAP Motor Regulation.

(MCAP = Minimum Current Adaptive Pulse)

In order to reduce the motor current consumption to its absolute minimum for a given mechanical load (i.e., required torque), the motor drive parameters are adapted during **each** motor pulse to the existing load condition.

Adaption to a given motor is done by appropriate selection of the parameters  $t_1$ ,  $f_{chop}$ ,  $t_2$ ,  $t_{ref}$ ,  $t_{inc}$ ,  $t_{dec}$ ,  $t_{crit}$ ,  $t_{max}$ ,  $t_3$  and  $i_{ref}$ .

### Regulation Algorithm

The regulation is performed in the following way (please refer to figure 6 and 7):

At the end of  $t_1$ , the motor current  $I_{MOT}$  is measured and this measured value is stored.

After measurement of the motor current, a reference current  $i_{ref}$  is generated, which is typically 100% of the previously (at the end of  $t_1$ ) measured motor current and the actual motor current is compared every 61  $\mu s$  with  $i_{ref}$ .

If the motor current is found to be below  $i_{ref}$ , then a drive pulse  $t_2$  is generated (see figure 6). At the end of the first  $t_2$  pulse, the motor current is again compared to  $i_{ref}$  and as soon as the motor current falls again below  $i_{ref}$ , a new drive pulse  $t_2$  is generated (see figure 6).

This is continued as long as the motor current drops below  $i_{ref}$  within a time shorter than  $t_{ref}$  – after the preceeding drive pulse  $t_2$ , or until the time  $t_{crit}$  has elapsed.

If the motor current does not drop below  $i_{ref}$  during the time  $t_{ref}$ , then no further motor pulses  $t_2$  are generated (see figure 6).

In addition to the above, the following takes place in order to achieve reliable function over a wide range of mechanical load and power supply voltage (and minimum current consumption for a given load condition).

At power-up or with  $RESET = V_{DD}$ ,  $t_{on}$  is set to its maximum value (duty cycle 50% or 100%).

If the motor pulses  $t_2$  are terminated before  $t_{dec}$  has elapsed, then  $t_{on}$  is decremented, for the following motorpulse.

$t_{on}$  may be decremented repetitively (after each motor pulse), until the  $t_2$  pulses are terminated after  $t_{dec}$  or until a minimum width of  $t_{on}$  is reached.

If the motor pulses  $t_2$  are terminated after  $t_{dec}$  but before  $t_{inc}$  has elapsed (which means that the duty cycle of the chopped pulses –  $t_{on}/t_{off}$  – during  $t_1$  is well adapted to the mechanical load), then  $t_{on}$  remains unchanged.

If the motor pulses  $t_2$  are not terminated at the end of  $t_{inc}$ , then  $t_{on}$  is incremented, for the following motorpulse.

$t_{on}$  may be incremented repetitively (after each motor pulse) until the  $t_2$  pulses are terminated before  $t_{inc}$  – or until a maximum width for  $t_{on}$  of 50% or 100% duty cycle is reached.

If the motor pulses  $t_2$  are not terminated at  $t_{crit}$ , then an additional motorpulse  $t_3$  (duty cycle 50% or 100%) will be generated (see figure 7).

In this case, the following motorpulse  $t_1$  starts again with its maximum duty cycle (i.e., same condition as after power-up or RESET =  $V_{DD}$ ).

## Operating Characteristics

$V_{SS} = 0$ ,  $V_{DD} = 3.0$  V,  $T_{amb} = +25^\circ\text{C}$ ; unless otherwise specified. All voltage levels are measured with reference to  $V_{SS}$ . Test crystal as specified below.

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
Operating voltage	Functional test (figure 2)	V <sub>DD</sub>	2.2		3.6	V
Operating current	C <sub>OUT</sub> = 16 pF, C <sub>TR</sub> = 15 pF R <sub>L</sub> = ∞	I <sub>DD</sub>		120	300	nA
RESET input current	RESET = V <sub>DD</sub>	I <sub>R</sub>		8		nA
Motor outputs						
Motor output current	R <sub>L</sub> = 2 kΩ, V <sub>DD</sub> = 3.0 V	I <sub>M</sub>	± 1.35			mA
Motor period		t <sub>M</sub>	2			s
Motor pulse width		tpw	See option list			ms
Oscillator						
Stability vs. supply voltage	ΔV <sub>SS</sub> = 100 mV, C <sub>TR</sub> = 5 pF	Δf/f		0.1		ppm
Start-up voltage	within 2 sec	V <sub>ST</sub>	2.4			V
Integrated input capacitance		C <sub>OSCIN</sub>		2		pF
Integrated output capacitance		C <sub>OSCOUT</sub>	See option list		22	pF

**Note 1:** Typical parameters represent the statistical mean values

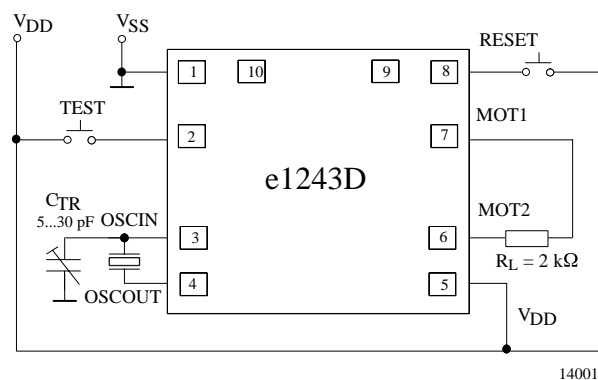


Figure 2. Functional test

## Test Crystal Specification

Frequency	$f = 32768$ Hz
Series resistance	$R_S = 30$ k $\Omega$
Static capacitance	$C_O = 1.0$ pF
Dynamic capacitance	$C_1 = 2.5$ fF
Load capacitance	$C_L = 8$ pF

Note: Maximum series resistance  $R_S = 50$  k $\Omega$

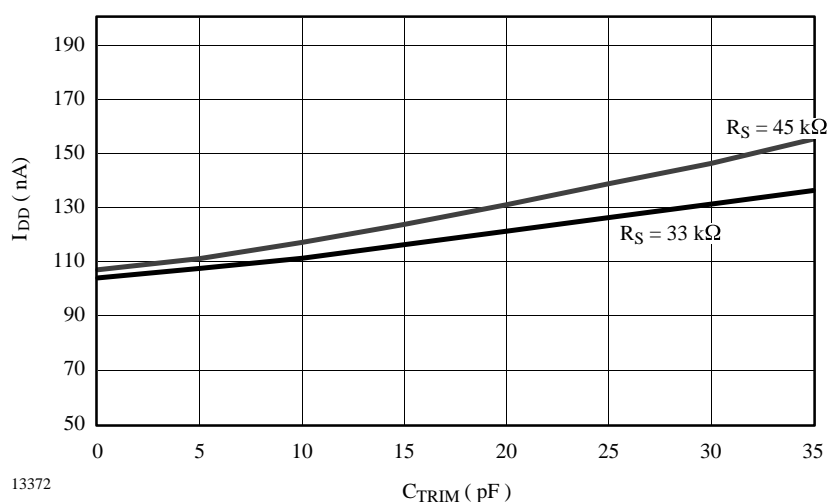
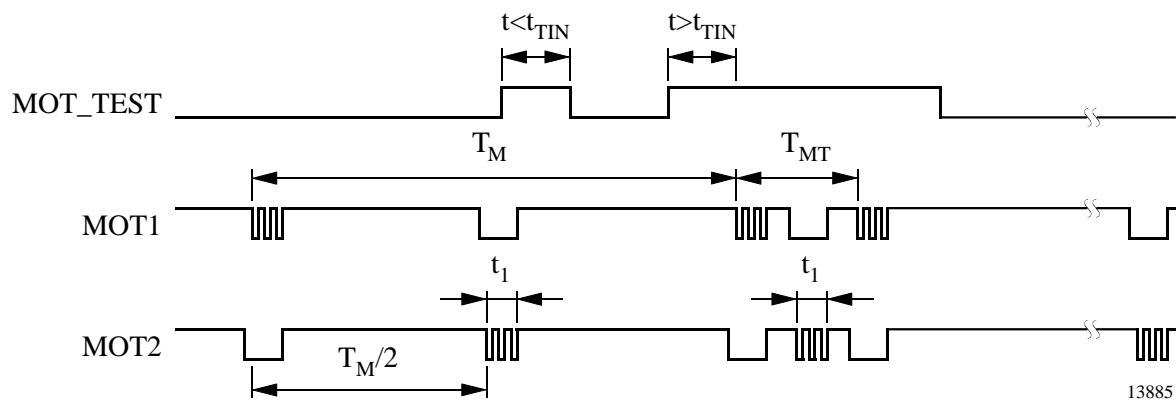
Figure 3.  $I_{DD} = f(C_{TRIM}, \text{quartz})$ 

Figure 4. Motor drive outputs in normal mode and motortest

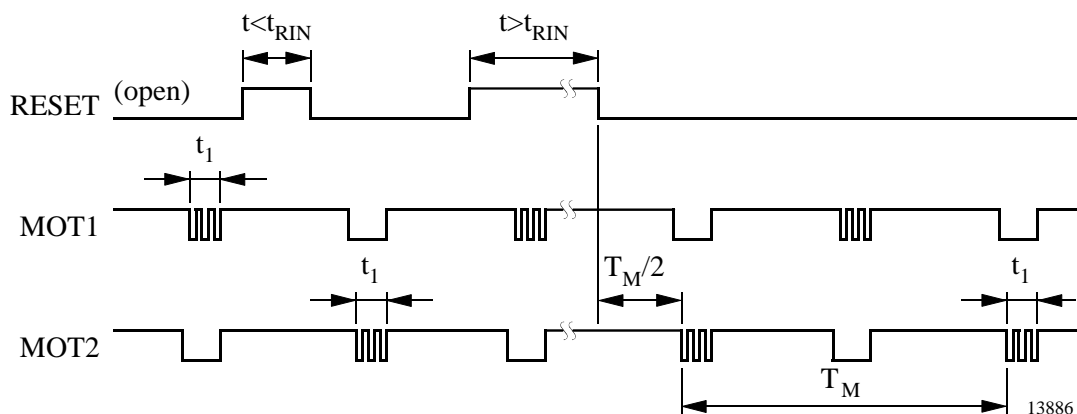


Figure 5. Motor drive outputs and reset

**Note:** For sake of simplicity, only the  $t_1$ -portion of the motorpulse  $t_{PW}$  is shown in figure 4 and figure 5. The complete shape of the motorpulse is shown in figure 6 and figure 7.

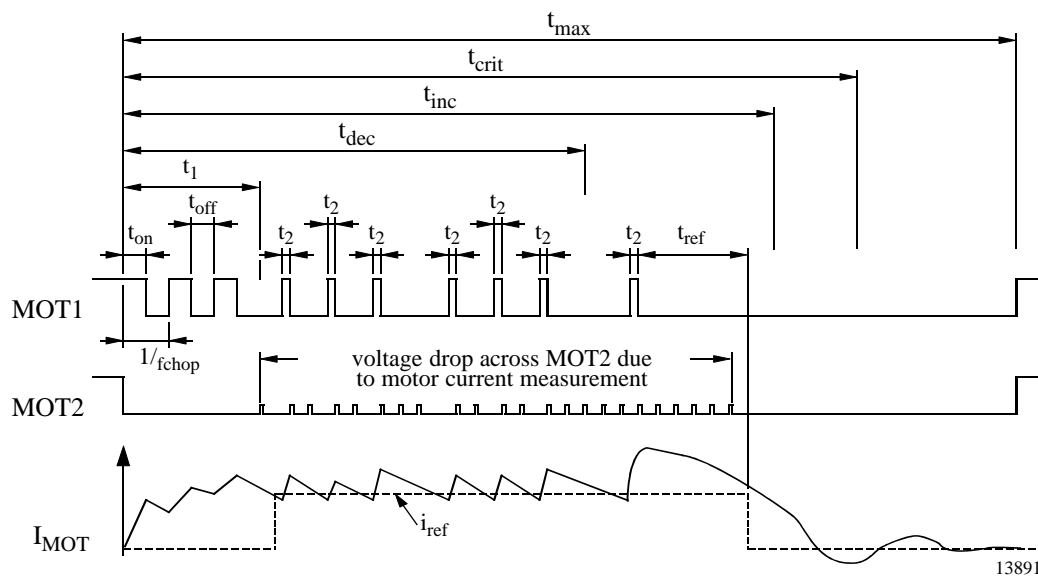


Figure 6. Motor pulse shape

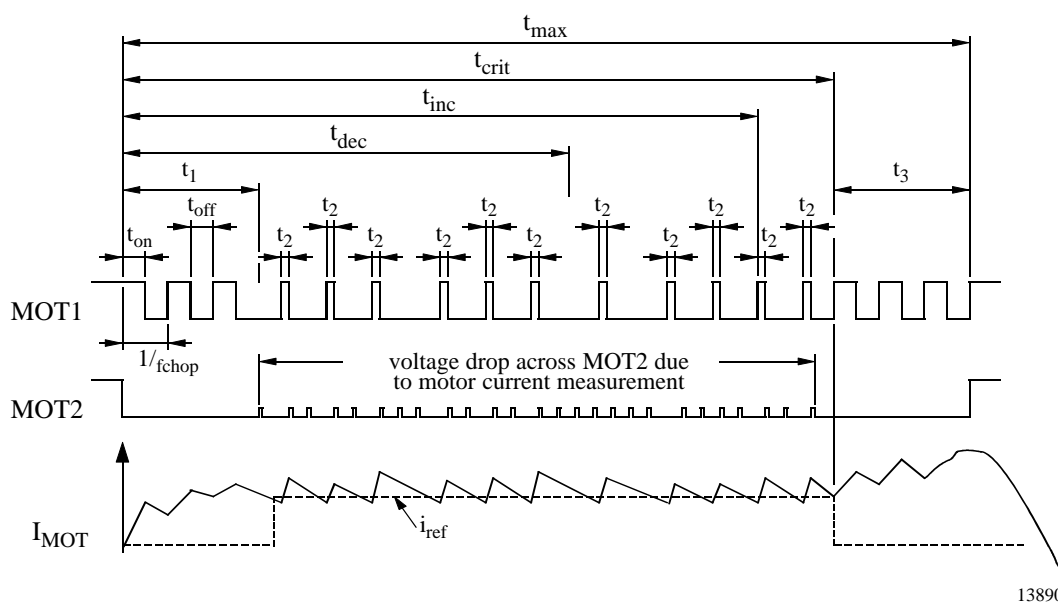


Figure 7. Motor pulse shape (no rotation at  $t_{crit}$ )

Table 4. Option list e1243D–

Option	Integrated Capacitance *)									
	C <sub>OSCIN</sub> pF	C <sub>OSCOUT</sub> pF	Pad 1	Pad 2	Pad 3	Pad 4	Pad 5	Pad 6	Pad 7	Pad 8
–C	2	17	M_ TEST	Reset	OSCOUT	OSCIN	V <sub>SS</sub>	MOT2	MOT1	V <sub>SS</sub>

\*) on-chip stray capacitance included

Options for motor control

Option		–C					
Symbol	Conditions	Value	Value	Value	Value	Value	Unit
T <sub>M</sub>		2					s
t <sub>1</sub>		3.9					ms
f <sub>chop</sub>		2048					Hz
t <sub>onmax</sub>	50%	244					µs
t <sub>onmin</sub>	37.5%	183					µs
t <sub>3</sub>	t <sub>on</sub> = 50%	3.9					ms
t <sub>dec</sub>		6.34					ms
t <sub>inc</sub>		7.81					ms
t <sub>crit</sub>		9.27					ms
t <sub>max</sub>		13.18					ms
t <sub>2</sub>		61					µs
t <sub>ref</sub>		732					µs
T <sub>MT</sub>	16 steps per second	125					ms
T <sub>MTEST</sub>	64 steps per second	31.25					ms
i <sub>ref</sub>	From I measured	80					%
i <sub>refmin</sub>		160					µA

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