CMOS Circuit for Car Quartz Clocks with Electrical Forward Setting

1. General

The CLK5010 can be used for driving analog clocks that advance at either second or minute intervals. With minute-controlled mechanisms, forward setting is made electrically by depressing a pushbutton switch. With second-controlled mechanisms, the minute and second hands are set mechanically.

The IC contains an oscillator circuit for a 4.194812 MHz quartz and a switchable frequency divider whose output frequency in the normal mode is 0.5 Hz for clocks with a second hand or 1/120 Hz for minute-controlled mechanisms. Change-over takes place at the min/$\overline{\text{sec}}$ input.

With seven tuning leads of the frequency divider, the output frequency can be adjusted to 0.5 Hz or 1/120 Hz to an accuracy of ± 0.95 ppm.

In the normal mode, the conduction phase of the alternating current through the motor winding is 125 ms. The motor makes a step every time the current direction changes.

Electrical forward setting is actuated with a pushbutton switch at the setting input. Each time the switch is briefly pressed, a motor step takes place in forward direction.

If this switch is pressed forward for longer than approx. 1.2 sec, fast electrical adjustment takes place with 21 steps per second. When the setting switch is pressed, the second counter is erased so that the clock is synchronized to the full minute during adjustments.

With second-controlled mechanisms, the setting input is blocked and the minute and second hands are set mechanically.

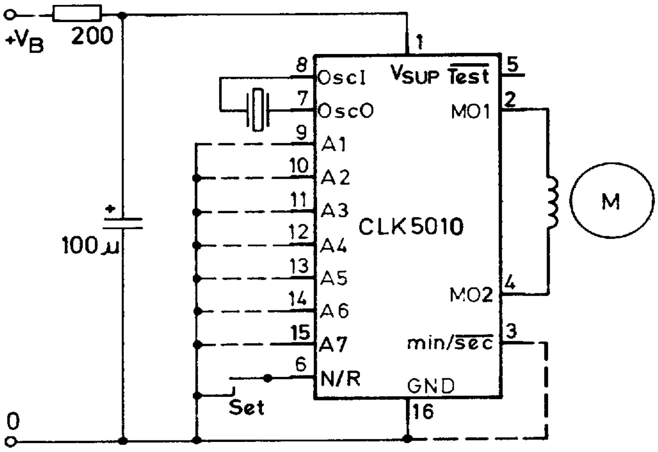

Fig. 1-1:
CLK5010 Application Circuit Minute Mode Operation

2. Outline Dimensions and Pin Connections

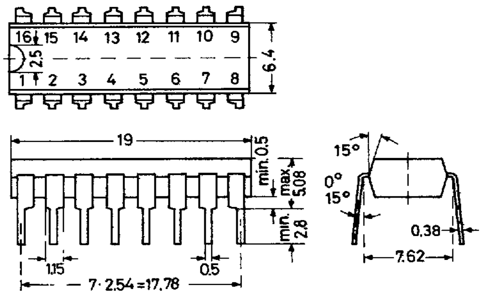

Fig. 2-1:
Plastic Package 20A16 according to DIN 41870
Weight approx. 1.1 g, Dimensions in mm

2. Outline Dimensions and Pin Connections

Pin	Function
1	Positive Supply Voltage Input V_{SUP}
2	Motor Output MO1
3	Programming Input min/$\overline{\text{sec}}$
4	Motor Output MO2
5	Test Input $\overline{\text{Test}}$
6	Setting Input N/R
7	Oscillator Output OscO
8	Oscillator Input OscI
9	Adjustment Input A1 (LSB)
10	Adjustment Input A2
11	Adjustment Input A3
12	Adjustment Input A4
13	Adjustment Input A5
14	Adjustment Input A6
15	Adjustment Input A7 (MSB)
16	Ground, 0 V

3. Functional Description

The analog clock IC CLK5010 is supplied from the unswitched electrical system of the vehicle, buffered with an RC network, via its supply connections Pin 1 and Pin 16. The CLK5010 is protected against overvoltage by means of an integrated Zener diode.

The rated frequency of the quartz oscillator is 4194812 Hz.

For clocks fitted with a second hand, the motor output pulses in phase opposition should be exactly ½ Hz; for clocks with a minute hand only, they should be exactly 1/120 Hz.

The scatter of the quartz frequency can be balanced by an adjustable division ratio of the timer. The division factor between the quartz oscillator input and the motor output is adjustable in 128 steps between $2^2 \times (2^{21}+0)$ and $2^2 \times (2^{21}+508)$ for second hand operation and between $60 \times 2^2 \times (2^{21}+0)$ and $60 \times 2^2 \times (2^{21}+508)$ for minute hand operation by means of the adjustment inputs A1 to A7 (Pins 9 to 15).

The maximum output frequency is set when all adjustment pins are open circuit. If one or more adjustment terminals are grounded, the output frequency decreases. Pin 9 gives the smallest adjustment of 1.9 ppm. Pin 10 affords the next larger step of 3.8 ppm and so forth, up to Pin 15 which enable an adjustment step of 122 ppm to be obtained.

If all adjustment terminals are grounded, the output frequency is reduced by 242 ppm.

A test input (Pin 5) is provided in order to facilitate the adjustment procedure and to permit swift testing of the CLK5010. Three different input levels are recognized by this input:

$0.8\,V_1 \leq V_5 \leq V_1$: Normal operation mode
$0.4\,V_1 \leq V_5 \leq 0.6\,V_1$: Test mode 1
$0\,V \leq V_5 \leq 0.2\,V_1$: Test mode 2

Test mode 1:
Ten flip-flop steps in the top part of the time counter chain (512 kHz-FF to 1024 Hz-FF) are masked out. These flip-flop steps belong to the divider which is adjustable with the adjustment inputs A1 to A7. The 128 division values which are adjustable in the second mode are shifted as a result of this acceleration of the time sequences to values of $2^2 \times (2^{11}+0)$ (all adjustment terminals open) to $2^2 \times (2^{11}+508)$ (all adjustment terminals at L level). The values for the accelerated minute mode are obtained by multiplying the above values by a factor of 60.

The acceleration factor depends on the digital information present at the adjustment inputs and ranges between 1024 $= 2^{10}$ and 820.7. The value 1024 is obtained when all adjustment inputs are open-circuit.

Test mode 2:
The top part of the time counter chain, including the 10 flip-flops masked out in test mode 1, are checked in test mode 2. For this purpose, the output frequency of the top divider half of 512 Hz is divided by 4. The frequency of 128 Hz which is obtained appears at the motor outputs with a pulse duty factor of 0.25. This frequency corresponds to the oscillator frequency divided by exactly 2^{15} and remains unaffected by the information present at the adjustment inputs.

By means of a precise measurement of the 128 Hz output frequency in test mode 2, the adjustment procedure determines the digital correction that is required in order to adjust the clock.

Table 3-1: Motor Output Frequency resp. Divider Ratio after Adjustment in Test Mode 1 and Coding of the Adjustment Inputs dependent on the Oscillator Frequency in Test Mode 2

Osc. Frequency f_7 Hz	Motor Output Frequ. in Test Mode 2 $f_2=f_4$ Hz	Coding of Adjustment Inputs Pin No 15 14 13 12 11 10 9 Binary	Dec.	Motor Output Frequency $f_2=f_4$ resp. Divider Ratio $f_7/f_2=f_7/f_4$ after Adjustment — Normal Mode — Seconds $f_7/f_2=f_7/f_4$	Normal Mode — Minutes* $f_7/f_2=f_7/f_4$	Test Mode 1 — Seconds $f_2=f_4$ Hz	Test Mode 1 — Seconds $f_7/f_2=f_7/f_4$	Test Mode 1 — Minutes* $f_2=f_4$ Hz	Test Mode 1 — Minutes* $f_7/f_2=f_7/f_4$ ×60
4194304	128.00000	H H H H H H H	127	8388608	503316480	512.00000	8192	8.533334	491520
4194312	128.00024	H H H H H H L	126	8388624	503317440	511.00293	8208	8.516715	492480
4194320	128.00049	H H H H H L H	125	8388640	503318400	510.00974	8224	8.500162	493440
4194328	128.00073	H H H H H L L	124	8388656	503319360	509.02039	8240	8.483673	494400
4194336	128.00098	H H H H L H H	123	8388672	503320320	509.03488	8256	8.467248	495360
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
4195288	128.03003	L L L L H L L	4	8390576	503434560	412.92206	10160	6.882034	609600
4195296	128.03027	L L L L L H H	3	8390592	503435520	412.27359	10176	6.871226	610560
4195304	128.03052	L L L L L H L	2	8390608	503436480	411.62717	10192	6.860453	611520
4195312	128.03076	L L L L L L H	1	8390624	503437440	410.98276	10208	6.849713	612480
4195320	128.03101	L L L L L L L	0	8390640	503438400	410.34036	10224	6.839006	613440

* f_2 and f_4 are the motor output frequencies without considering the repeat pulse

Second or minute operation is programmed via the hard-wired min/$\overline{\text{sec}}$ programming input (Pin 3).

Pin 3 High level: Minute operating mode
Pin 3 Low level: Second operating mode

Fig. 3-1 shows the behavior of the motor output in the normal operating mode. The motor outputs MO 1 and MO 2 behave in phase opposition in the normal operating mode with a pulsewidth of 125 ms for the High phase in the second and minute operation mode.

To provide greater reliability in the minute mode, a repeat pulse is provided 30 seconds after every regular minute pulse, in each case at the same motor output i.e. passing through the motor winding in the same direction of current. This produces a minute step in cases where the stepping motor has failed to respond to the regular pulse (e.g. due to an interruption in the voltage supply of the vehicle). Normally, the repeat pulse has no effect if the minute step has taken place in response to the regular motor pulse.

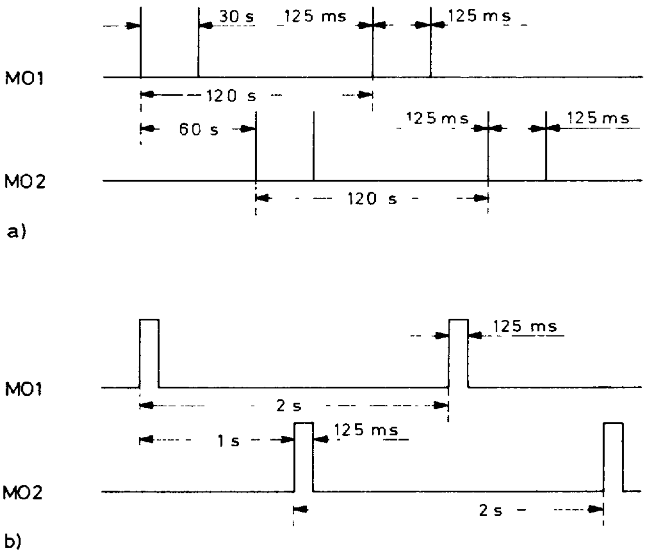

Fig. 3-1:
Motor Output Pulses in Normal Operation
a) Minute Mode
b) Second Mode

As electrical adjustment of the clock can only be achieved within an acceptable time in the case of minute movements, the setting input N/R (Pin 6) is locked when the min/$\overline{\text{sec}}$ programming input is in the second mode setting.

By connecting the motor winding to the motor outputs MO 1 and MO 2, which are operated in phase opposition, there is a facility for inverting the direction of current in the winding. One motor step takes place each time the direction of current is changed. The preferred position of the two motor outputs is Low so that the winding is short-circuited without current and with low impedance. To induce a step, the motor output concerned is switched to High. This causes the current to flow in the opposite direction to that of the preceding step.

The operating mode is selected with a pushbutton switch at the setting input N/R, Pin 6:

Setting input Low level: Forward setting
Setting input open: Normal mode.

Electrical setting is only possible in the minute mode. The setting input N/R is blocked in the second mode.

Each brief actuation of the setting switch causes the minute hand to make a step. Setting frequencies up to 5 Hz at the setting input are processed to give the same number of motor steps. If the setting switch is depressed continuously for more than approx. 1.2 seconds, forward setting of the minute hand takes place. This involves an initial acceleration phase after approx. 1–2 seconds which lasts for 2 seconds with 8 motor steps with a motor frequency of 2 Hz (corresponding to 4 steps/sec.). The second acceleration phase takes place after approx. 3 seconds and provides 8 additional motor steps with a motor frequency of approx. 6 Hz. The final speed is reached after approx. 4 seconds with a motor frequency of about 10 Hz (corresponding to approx. 20 steps/sec.).

The pulse duty factor of the motor pulses in the fast setting phase is 0.5. A 12-hour adjustment is possible in approx. 35 seconds.

When the setting switch is released the setting process is interrupted in such a way that the last motor pulse is fully completed. The second counter is reset to zero after every setting operation to allow the clock to be synchronized to the second.

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4. Electrical Characteristics

All voltages referred to ground (Pin 16), if not stated otherwise

4.1. Absolute Maximum Ratings

Symbol	Parameter	Min.	Max.	Unit
V_1	Supply Voltage	−0.5	V_{Z1}	V
V_i	Input Voltage (i=3, 5, 6, 8, 9, . . ., 15)	−0.5	V_1	V
I_i	Input Current (i=3, 5, 6, 8, 9, . . ., 15)	−10	+10	mA
V_q	Output Voltage (q=2, 4)	−0.5	V_1	V
V_7	Output Voltage	V_1 − (4 V to 6 V)	V_1	V
I_q	Output Current (q=2, 4)	−50	+50	mA
I_7	Output Current	−10	+10	mA
T_A	Ambient Operating Temperature Range	−40	+85	°C
T_S	Storage Temperature Range	−55	+125	°C
I_{1S}	Surge Input Current for t=2 ms for t=0.1 ms	 – –	 100 500	 mA mA

4.2. Recommended Operating Conditions

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_1	Supply Voltage	5	12	15.5	V
f_p R_r	Parallel Resonance Frequency of the Quartz at C_L = 17 pF Effective Series Resistance of the Quartz at C_L = 17 pF	4.194612 –	4.194812 150	4.195002 –	MHz Ω
 R_M L_M	Motor Coil Resistance Inductivity	 365 688	 406 860	 446 1032	 Ω mH

4.3. Characteristics at $-40\ °C \leq T_A \leq 85\ °C$, $+5.0\ V \leq V_1 \leq V_{Z1}$, if not stated otherwise

Symbol	Parameter		Min.	Typ.	Max.	Unit	Conditions
I_1	Current Consumption		–	–	3	mA	$V_1 = 12\ V$, $f_{osz} = 4.194812\ MHz$ $V_3 = V_9 = V_{10} = V_{11} = V_{12} = V_{13} = V_{14} = V_{15} = 0\ V$; other inputs and outputs open
ΔI_1	Change of Current Consumption at Level Change at MO1/MO2		–	–	0.3	mA	same test conditions as above
V_{Z1}	Zener Voltage		16	–	19	V	$I_1 = 15\ mA$, $T_A = 25\ °C$
ΔV_{Z1}	Change of Zener Voltage		–	–	400	mV	$I_1 = 10\ mA$ to $20\ mA$, $T_A = 25\ °C$
αV_{Z1}	Temp. Coeff. of Zener Voltage		–	12	–	mV/K	$T_A = -40\ °C$ to $+85\ °C$
V_{iL}	Input Voltage	Low	0	–	$0.1\ V_1$	–	i = Pins 3, 9 to 15
V_{iH}		High	$0.7\ V_1$	–	V_1	–	
$-I_{iL}$	Input Current	Low	–	–	50	µA	$V_i = 0\ V$, $V_1 = 12\ V$
$-I_i$			5	–	–	µA	$V_{1-i} = 0.5\ V$, $V_1 = 12\ V$
I_{iH}		High	-10	–	10	µA	$V_{1-i} = 0\ V$; $V_1 = 12\ V$
V_{5L}	Input Voltage	Low	0	–	$0.1\ V_1$	–	ON level for test mode 2
V_{5LH}			$0.4\ V_1$	–	$0.6\ V_1$	–	ON level for test mode 1
V_{5H}		High	$0.8\ V_1$	–	V_1	–	
$-I_{5L}$	Input Current	Low	–	–	50	µA	$V_5 = 0\ V$, $V_1 = 12\ V$
$-I_5$			5	–	–	µA	$V_{1-5} = 0.5\ V$, $V_1 = 12\ V$
$-I_{5H}$		High	-10	–	10	µA	$V_{1-5} = 0\ V$, $V_1 = 12\ V$
V_{6L}	Input Voltage	Low	0	–	$0.1\ V_1$	–	
V_{6H}		High	$0.7\ V_1$	–	V_1		
$-I_{6L}$	Input Current	Low	0.6	–	2.0	mA	$V_6 = 0\ V$, $V_1 = 12\ V$
I_{6H}		High	-10	–	10	µA	$V_{1-6} = 0\ V$, $V_1 = 12\ V$
V_{qL}	Output Voltage	Low	–	–	0.5	V	q = Pins 2, 4 $I_{OL} = 15\ mA$; $V_1 = 5\ V$; normal mode or forward setting
V_{1-qH}		High	–	–	1.0	V	$I_{OH} = -15\ mA$; $V_1 = 5\ V$; normal mode or forward setting
f_7	Oscillator Frequency		4.194707	4.194812	4.194917	MHz	$V_1 = 12\ V$; variation of oscillator frequency due to variation of IC parameters

Characteristics continued

Symbol	Parameter	Min.	Typ.	Max.	Unit	Conditions
$\Delta f_7/f_7$	Stability of Osc. Frequency	−5	–	+5	ppm	$V_1 = 12$ V frequency drift due to temperature dependence of IC parameters
$\Delta f_7/f_7$		–	–	1.7	ppm/V	$5\text{ V} \leq V_1 \leq 12\text{ V}$
$\Delta f_7/f_7$		–	–	1.8	ppm/V	$12\text{ V} \leq V_1 \leq V_{Z1} - 1\text{ V}$
t_{6L}	Duration of L Level for Identification	–	–	55	ms	
t_{6H}	Duration of H Level for Identification	–	–	23	ms	
f_7/f_2, f_7/f_4	Division Factor Normal Mode Second Mode	$2^2 \times (2^{21}+0)$	–	–	–	$V_3 = 0$ V; Pins 9 to 15 at H level
		–	–	–	$2^2 \times (2^{21}+508)$	$V_3 = 0$ V; Pins 9 to 15 at L level
	Minute Mode	$60 \times 2^2 \times (2^{21}+0)$	–	–	–	$V_{1-3} = 0$ V; Pins 9 to 15 at H level
		–	–	–	$60 \times 2^2 \times (2^{21}+508)$	$V_{1-3} = 0$ V; Pins 9 to 15 at L level
$\Delta f_2/f_2$, $\Delta f_4/f_4$,	Range of Output Frequency Adjustment	–	242	–	ppm	
df_2/f_2, df_4/f_4	Accuracy of Output Frequency Adjustment	−0.95	–	+0.95	ppm	
f_2, f_4	Motor Output Frequency at Forward Setting					
	1. speed	–	2	–	Hz	> 1.2 s; < 3.2 s
	2. speed	–	6.4	–	Hz	> 3.2 s; < 3.825 s
	3. speed	–	10.67	–	Hz	> 3.825 s
ν_2, ν_4	Pulse Intervall Ratio at Forward Setting	–	0.5	–	–	
	Testmode 2					$0\text{ V} \leq V_5 \leq 0.2\,V_1$
f_2, f_4	Motor Output Frequency	–	128	–	Hz	
ν_2/ν_4	Pulse Intervall Ratio	–	0.25	–	–	
	Testmode 1 Second Mode					$f_7 = 4194304$ Hz; $0.4\,V_1 \leq V_5 \leq 0.6\,V_1$; $V_3 = 0$ V; all adjustment terminals H level
f_2/f_4	Motor Output Frequency	–	512	–	Hz	
t_2, t_4	Pulse Width	–	122	–	µs	
f_7/f_2, f_7/f_4	Division Factor	–	8129	–	–	
	Testmode 1 minute mode					$f_7 = 4194304$ Hz; $0.4\,V_1 \leq V_5 \leq 0.6\,V_1$; $V_{1-3} = 0$ V; all adjustment terminals H level
f_2, f_4	Motor Output Frequency	–	8.53	–	Hz	
$t_R - t_M$	Time Intervall between Main Pulse and Repetition Pulse	–	29.3	–	ms	
t_2, t_4	Pulse Width	–	122	–	µs	
f_7/f_2, f_7/f_4	Division Factor	–	491520	–	–	