Univerza v Ljubljani
Fakulteta za elektrotehniko

Andrej Švigelj

Robotska roka za prestavljanje težjega električnega modula

Seminarska naloga

pri predmetu
Elektronska vezja

1. Uvod: Potrebe in ideja

Testiranje vzdržljivosti materiala glede na večje in večkratne temperaturne spremembe na močnostnem modulu zahteva več tisočkratno spreminjanje temperature, v točno določenih korakih in natančnih časovnih intervalih. Ker je ročno izvajanje takega števila ponovitev nemogoče, se je izkazala potreba po rešitvi, ki bi to opravljala avtomatsko. Spremembe temperature bi bilo najlažje izvesti s pomakanjem testiranca v vročo ali hladno vodo s konstantnima temperaturama.

Po predpisih mora biti nižja temperatura 0°C, višja pa 100°C, testiranec pa mora biti v vsaki vodi po 60 sekund, in ta cikel se mora več tisočkrat ponoviti. S tem je izvedeno tako testiranje občutljivosti modula na mnogokratno raztezanje, kot na pospešeno staranje materiala.

Osnovna zahteva je tako postala izdelava robotske roke, ki bi bila sposobna razmeroma težak močnostni modul pomakati v vročo in hladno posodo, hkrati pa morajo biti nastavljivi časi v eni in v drugi posodi. Vzdrževanje temperature v posodah ni zahteva za robotsko roko, ampak bo krmiljena drugje.

Idejne zahteve robota, z upoštevanjem komponent, ki so že bile na voljo, je bila naslednja:

- Krmiljenje z mikroprocesorjem (Motorola HC11)
- Upravljanje preko tipk
- Prikaz časov in št. ponovitev na LCD prikazovalniku
- Koračni motor za premik levo/desno
- Močnejši DC motor, s polžastim prenosom za dviganje in spuščanje
- Enota s krmilno elektroniko

2. Izbira komponent

Robot je bil izdelan po principu čim manjših stroškov, saj ni mišljen za redno serijsko proizvodnjo, ampak le za občasno delovanje. Pamet robota se skriva v mikroprocesorju Motorola HC11. LCD in tipke so iz odsluženega HP-jevega ploterja. Za dvigovanje težkega modula pa se je kot zelo primernega izkazal DC motor, ki je nekoč poganjal avtomobilske brisalce. Zaradi vgrajenega polžastega prenosa je tako odpadla zahteva po zavori, oz. držanju robotske roke v zgornjem položaju, med premikanjem iz ene v drugo posodo. Koračni motor, za premik levo in desno, pa se je našel v odsluženem tiskalniku. Za poganjanje le tega je bil kupljen poseben namenski krmilnik za koračne motorje. Iz tiskalnika je vzet tudi napajalni modul (5V in 43V) in pa kovinsko ohišje.
Končno lego zaznavajo optični senzorji, ki se ob dosegu skrajne lege optično prekinejo, posledično pa tudi električno. Veliko dela in spretnosti je zahtevala izdelave same robotske roke, nameščanje zobnikov, ležajev in podobno.

Robot je tako sestavljen iz večih sklopov. Na sami roki se nahajajo končni senzorji in motorji. Napajalnik (5V in 43V), krmilnik za koračni motor in releji za vklapljanje DC motorja se nahajajo v ločenem kovinskem ohišju. Zaradi preozkega ohišja pa so mikroprocesorska plošča, tipke in LCD dobili mesto v svoji škatli. Poudariti je treba, da ja za napajanje DC motorja potreben zunanji močnejši laboratorijski usmernik (12V/6A).

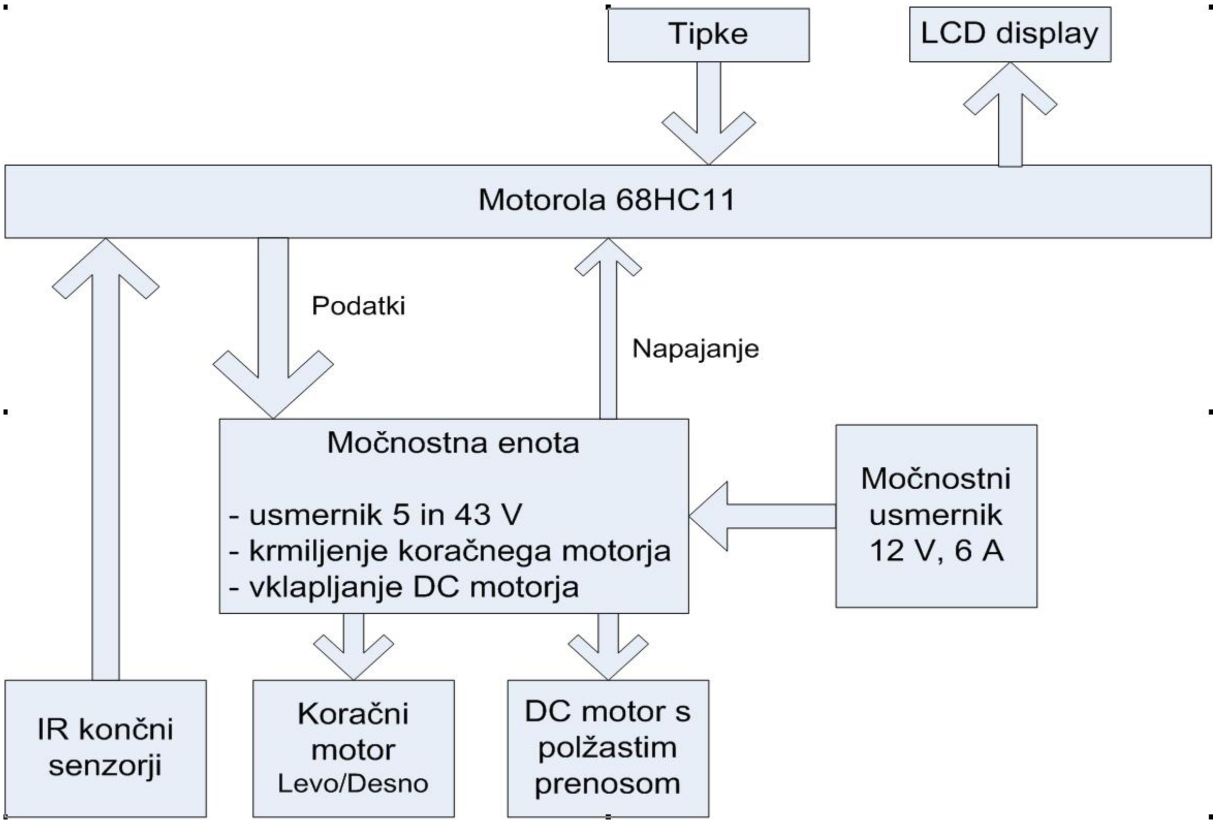
3. Delovanje

Po vklopu in resetu se na LCD prikazovalniku v zgornji vrstici prikažejo besede: CAS1, CAS2 in CIKELJ. Te besede nakazujejo pomen števil pod njimi. CAS1 pomeni čas v sekundah, ko je robot spuščen v prvi posodi. CAS2 pomeni čas v sekundah, ko je robot spuščen v drugi posodi. Cikelj pa pomeni število ciklov, ki jih bo robot še opravil. Robot se takoj po vklopu postavi v privzeto skrajno lego. Po nastavitvi časov in pritisku na ENTER robot začne izvajati cikle.
Čase in število ciklov se nastavlja s tipkami, ki so ob LCD zaslonu. S tipko levo/desno se pomikamo med različnimi časi, s tipkami gor/dol, hitro gor / hitro dol pa nastavljamo vrednosti. Po pritisku na tipko Enter robot začne z delovanjem. Če bi prišlo do nepredvidenih situacij ali v primeru nezgode je dodana še tipka STOP za takojšnjo ustavitev robota. Po taki ustavitvi je potreben ponoven pritisk na tipko reset.

Zaporedje delovanja v enem ciklu je sledeče:

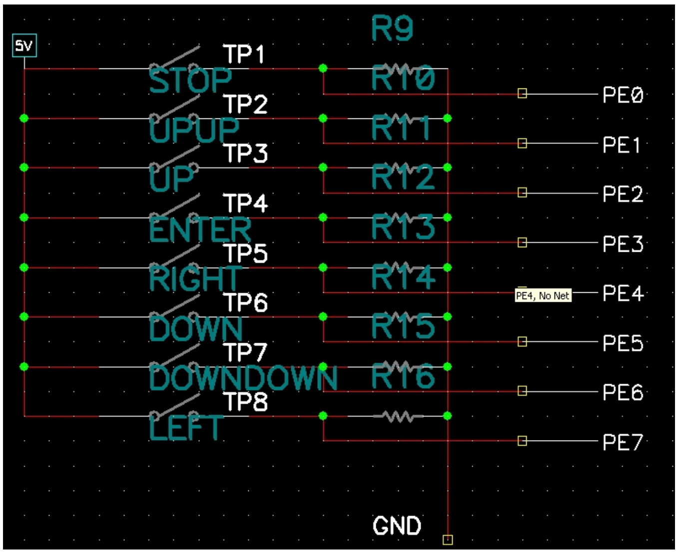
- spuščanje dol v prvo posodo, do prekinitve končnega senzorja 1.
- odštevanje sekund od časa 1
- dvigovanje do prekinitve končnega senzorja 2
- obračanje v levo do prekinitve končnega senzorja 3
- spuščanje v drugo posodo, do prekinitve končnega senzorja 1
- odštevanje sekund od časa 2
- dvigovanje do prekinitve končnega senzorja 2
- obračanje v levo, do prekinitve končnega senzorja 4
- zmanjšanje števila ciklov za 1

4. Blok shema sistema:



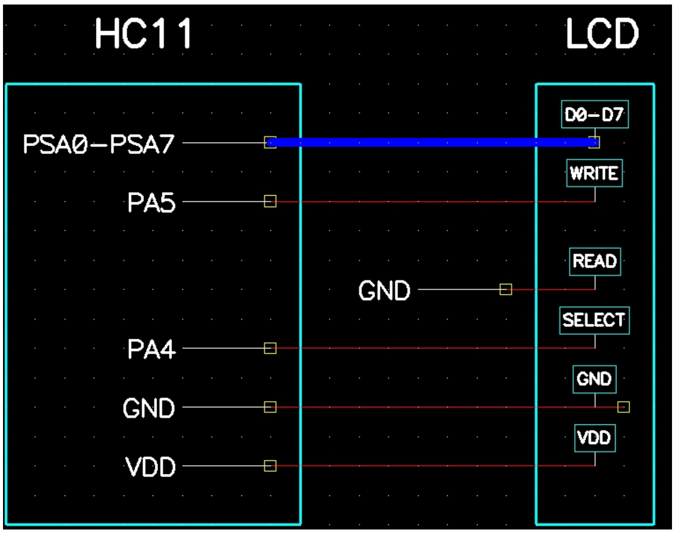
5. Električne sheme posameznih sklopov:

5.1 Vezalna shema za tipke:



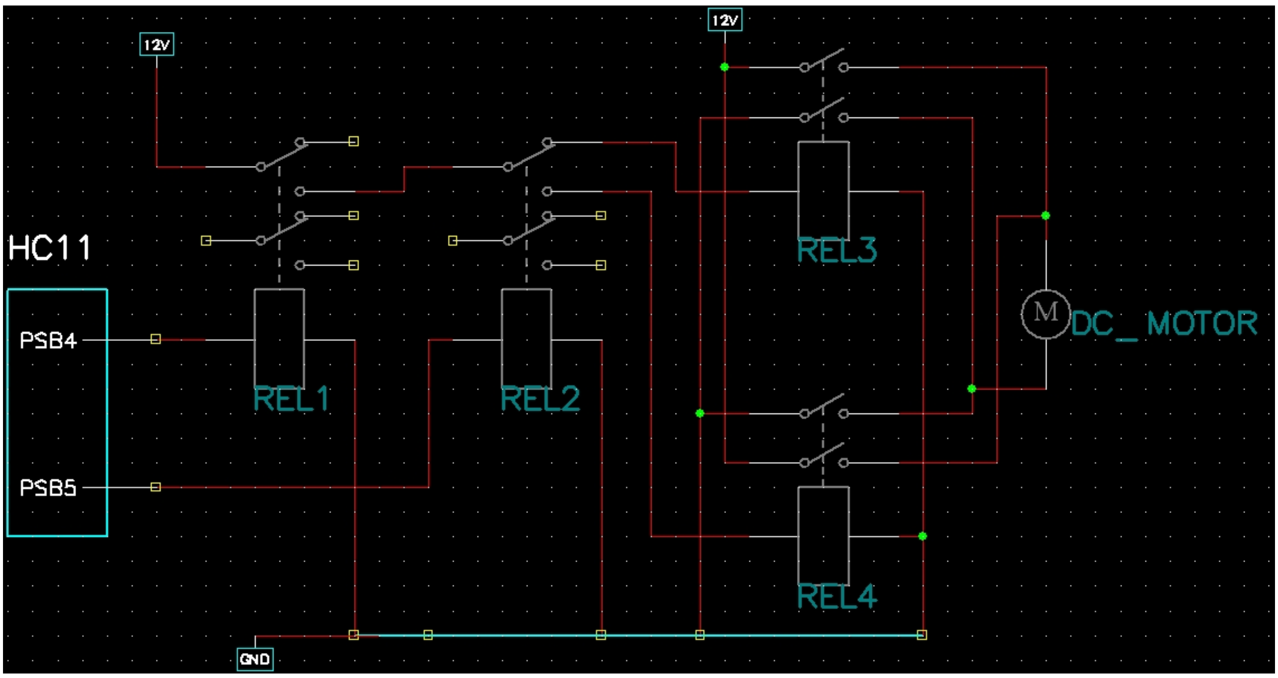
Tipke imajo zaradi preprečitve plavajočih nivojev, in nezaželjenih signalov, vezane 10 KΩ »pull-down« upore. Ob pritisku pa pride visoki nivo (5V) na vhod PE mikroprocesorja. Ta stalno bere tiste tipke, ki so v določenem stanju pričakovane, ostalih ne. Med delovanjem vedno bere tipko za prekinitev STOP, ki je namenjena urgentnim ustavitvam robota. Takrat se ta ustavi v tisti poziciji, kjer se je tisti trenutek nahajal. Za ponoven zagon je potreben pritisk na dodatno tipko RESET. (resetiranje mikroprocesorja). Robot se bo takrat postavil v prednastavljeno skrajno lego.

5.2 Shema priključitve LCD prikazovalnika:



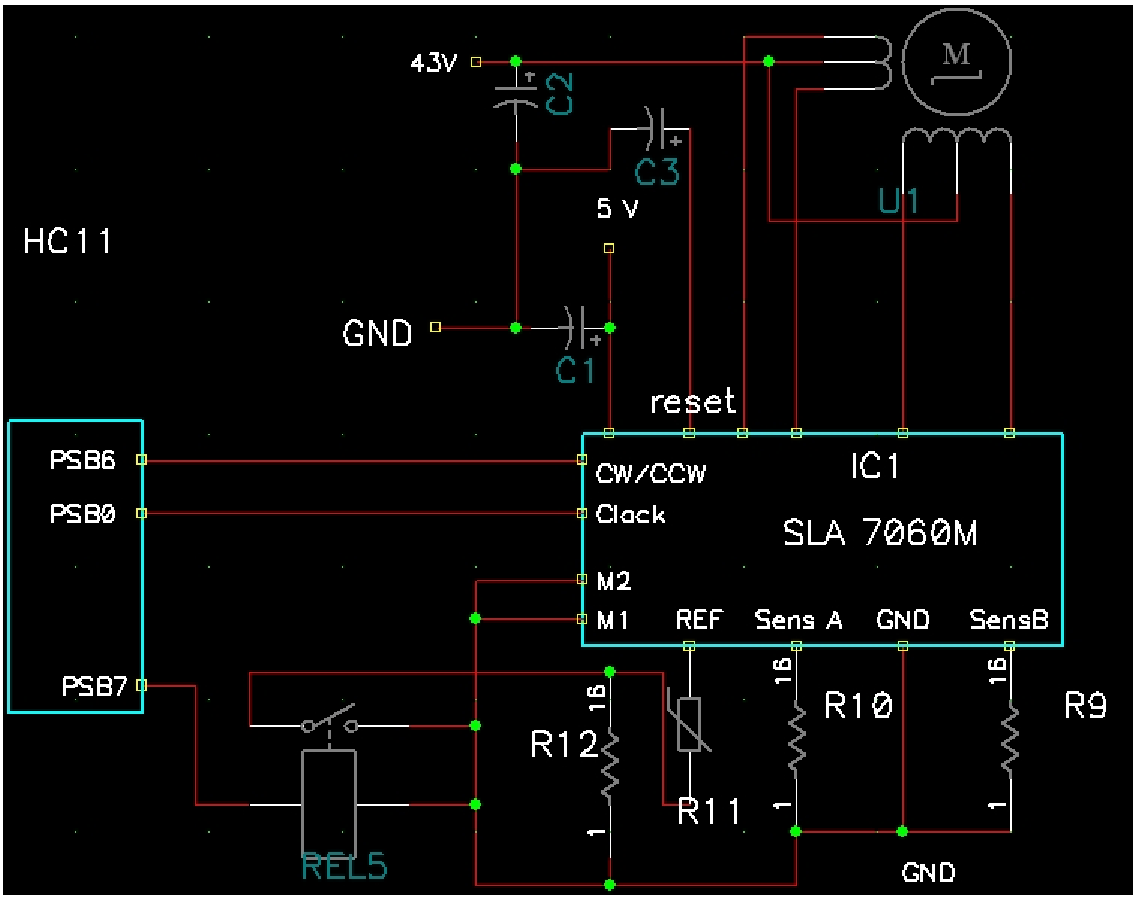
LCD prikazovalnik ni standarden, saj izhaja iz namenske naprave, a mi je vseeno uspelo najti potrebne podatke za upravljanje. Informacije o znakih pritekajo preko vhoda PSA mikrokrmilnika, kontrolni signali pa preko izhoda PA4 za izbiro in PA5 za pisanje. Za pisanje na LCD je potrebna posebna sekvenca kontrolnih signalov.

5.3 Shema priključitve DC motorja



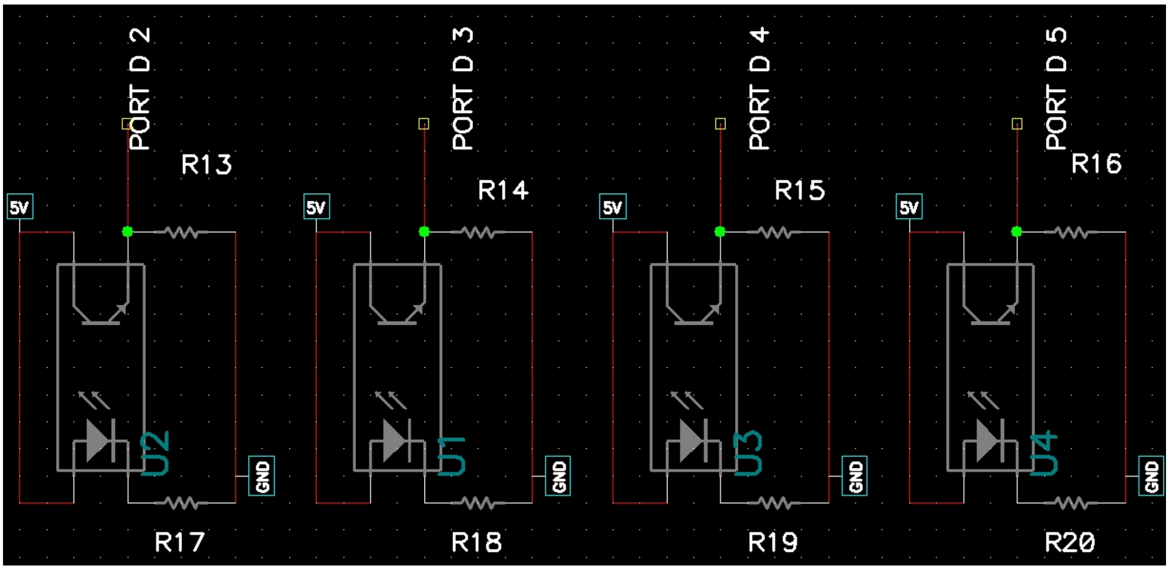
Kot že omenjeno, je DC motor napajan iz zunanjega, močnejšega usmernika, samo vrtenje in smer vrtenja pa je določena s stanjem dveh bitov na izhodu B mikrokontrolerja. En bit določa smer vrtenja, drugi pa vklop in izklop. Motor je logično zvezan preko dveh močnejših relejev, tako , da vklop enega pomeni vrtenje v eno smer, vklop drugega pa vrtenje v drugo smer. Ker sta bila ta dva releja prevelik zalogaj za šibke signale iz mikroprocesorja, je bilo potrebno vmes dodati še dva releja. To pa prinaša še eno pozitivno lastnost in sicer prepreko vklopa obeh močnih relejev hkrati in s tem povzročitve kratkega stika najmočjejšega električnega sklopa robota. Prvi manjši rele skrbi za vklop in izklop, drugi pa izbira med enim in drugim močnejšim relejem, fizično pa ne more biti na obeh položajih hkrati.

5.4 Shema priključitve koračnega motorja in njegovega krmilnika

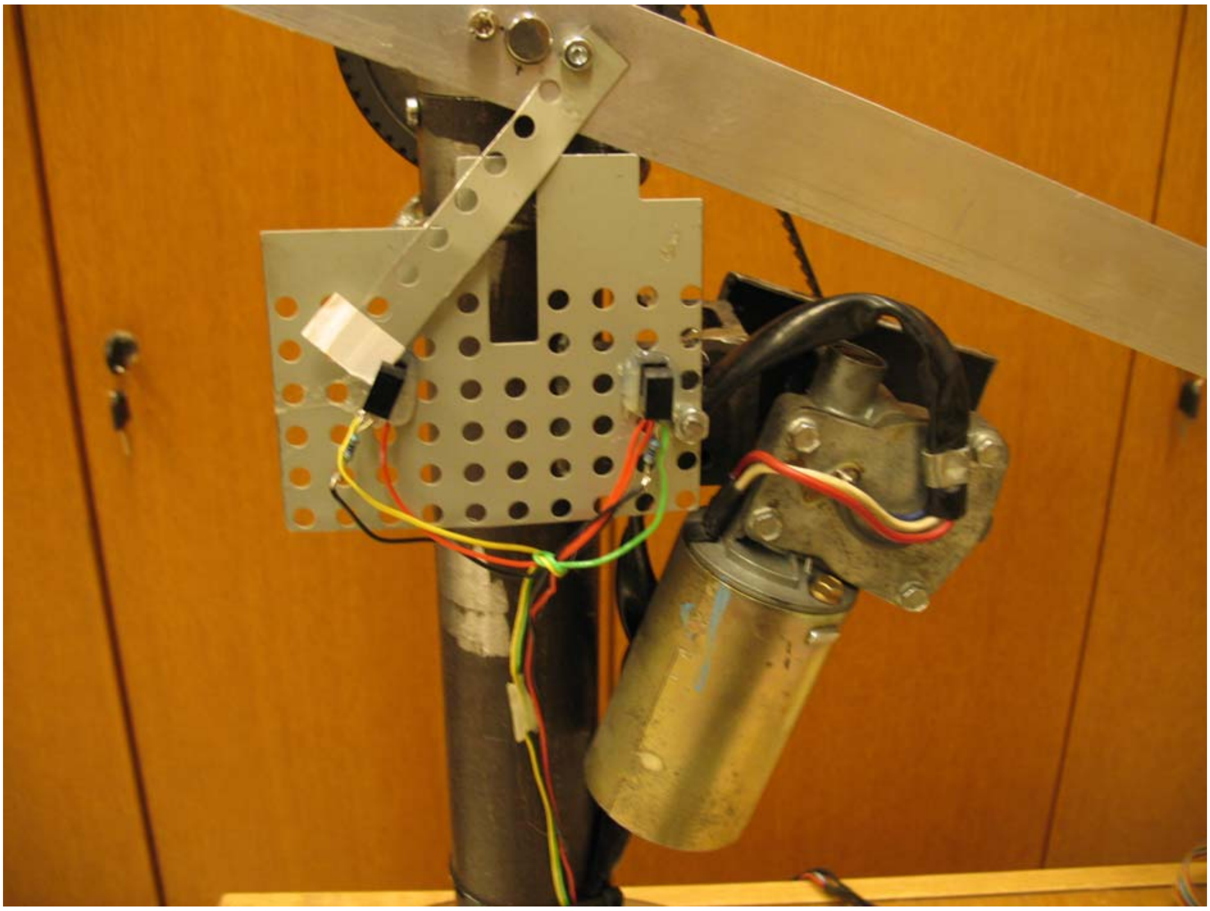


Krmilnik SLA7060M nam omogoča veliko možnosti, glede krmiljenja unipolarnih koračnih motorjev. Delovanje je za uporabnika precej preprosto. Iz mikrokrmilnika mu dovajamo urine impulze. Z vsakim impulzom motor premakne za en del koraka. Kot, za katerega se premakne določamo z dodatnima vhodoma M1 in M2. Izbiramo lahko med premikom za pol koraka, za četrtino, osmino ali šestnajstino koraka, ob vsakem urinem impulzu. Ker se pri tej aplikaciji uporablja konstantne korake, sta oba bita postavljena na fiksno vrednost. Dodaten digitalen vhod CW/CCW pa nam določa smer vrtenja.. Vhoda »sense« sta potrebna za merjenje in regulacijo toka na posameznih fazah, z vhodom »ref« pa se ta tok nastavlja oziroma, pri določeni napetosti pomeni stanje sleep. To dosežemo z relejem, ki kratko sklene R12, in nivo se ravno prav zniža.

5.5 Shema priključitve končnega senzorja



Upora za omejevanje toka sta prispajkana na senzor sam, oba skupaj pa na robotski roki. Informacije o senzorjih se berejo preko vhoda D na mikroprocesorju. Za čim boljše zmanjšanje napak, se vedno preverja le stanje tistega senzorja, ki je v tistem trenutku pomemben.

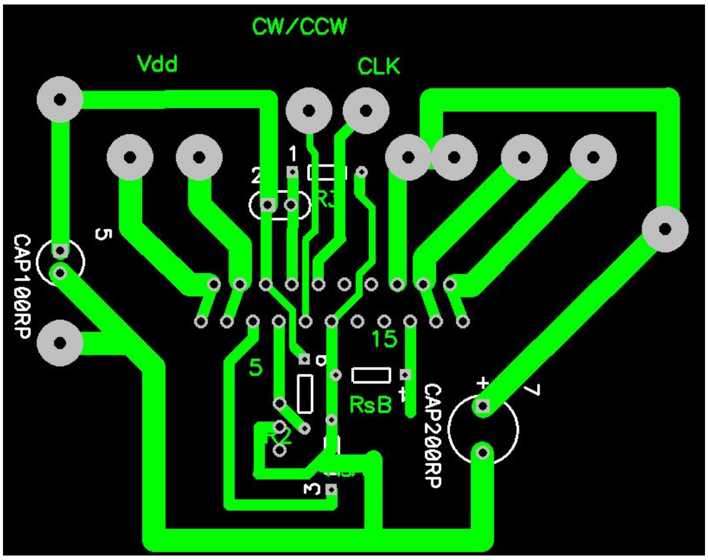


Izgled končnin senzorjev na robotu in DC motor s polžastim prenosom

6 Tiskano vezje

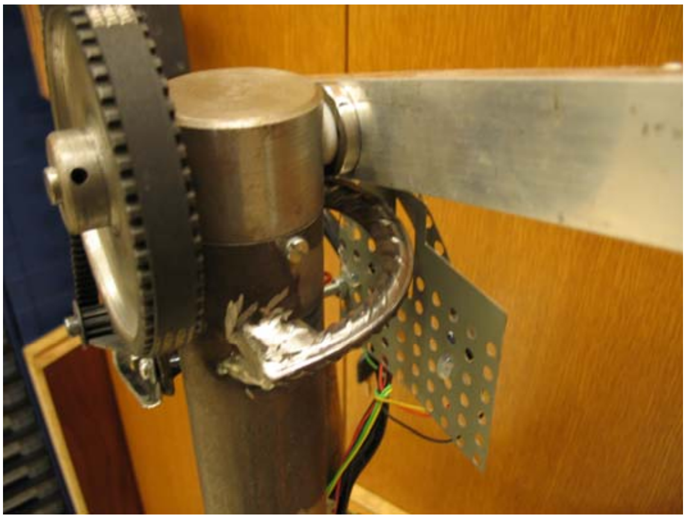
Precej komponent, na primer motorji in končni senzorji, so precej razporejeni po celem sistemu, zato je bilo treba posebej tiskano vezje izdelati le za krmilnik koračnega motorja in vezje za mikroprocesor, ki pa je standardno in že narejeno. Izdelovanje plošče za releje DC motorja zaradi malo komponent ni bila smiselna, in je uporabljena kar protoboard spajkalna plošča.

6.1 Tiskano vezje za krmilnik koračnega motorja



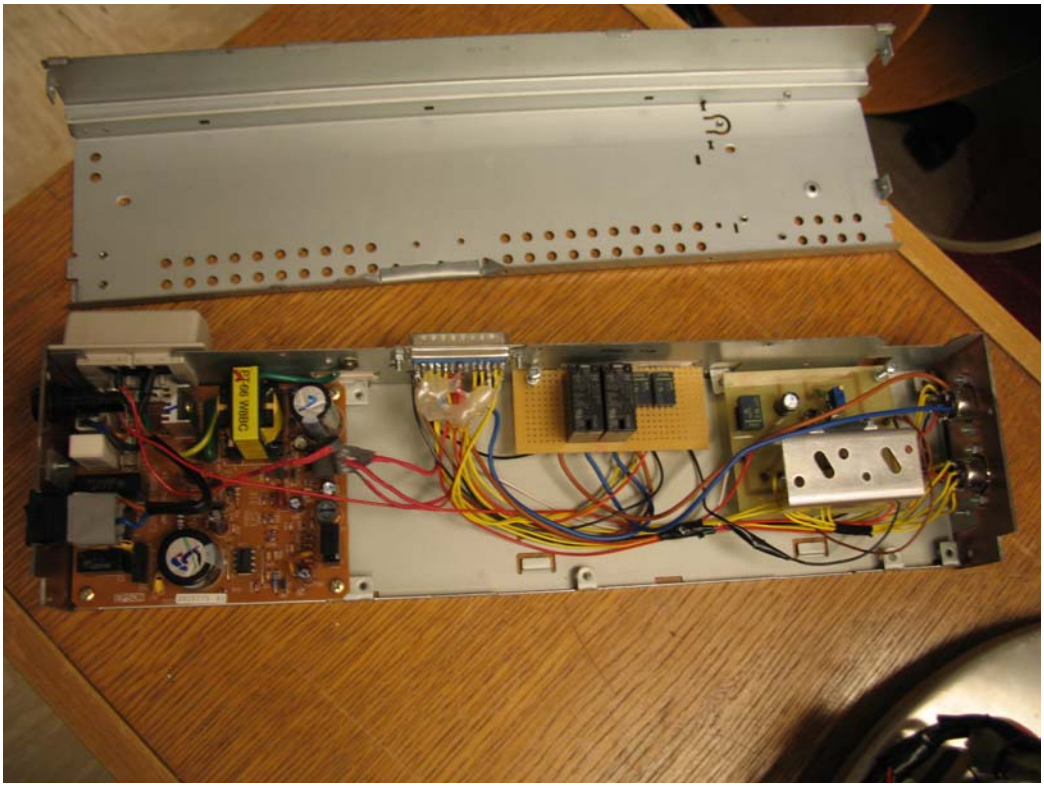
7 Testiranje in ugotovitve

Zaradi testiranja in nepredvidenih premikov roke, predvsem v smeri dvigovanja in spuščanja je bil na samo konstrukcijo privarjen močan kovinski omejevalnik, da ne bi roka slučajno udarila po tleh. V nasprotju s pričakovanji je bilo zelo malo težav s koračnim motorjem, ki je že takoj po priklopu deloval tako kot je bilo zamišljeno.

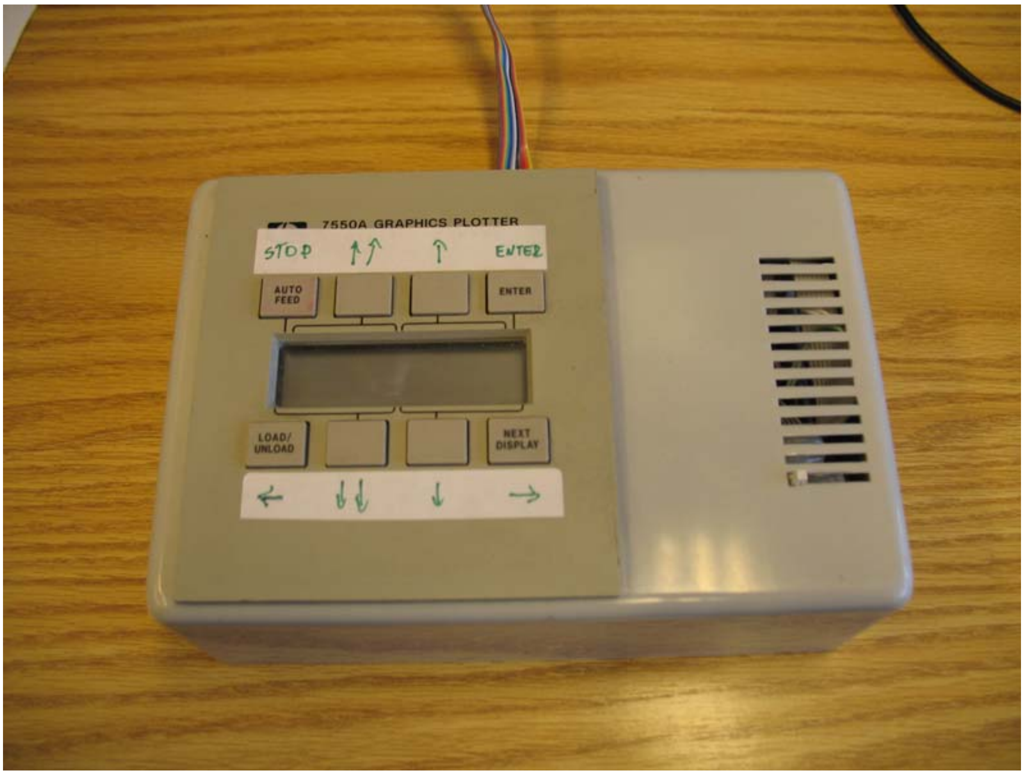


Fizična omejitev maksimalnega premika

Nekaj težav je povzročal tiskalniški napajalnik, saj signalna linija za mehak vklop/izklop ni bila nikamor vezana, in tako se je napajalnik sam prižigal in ugašal. Rešitev je bila izvedena s priklopom na fiksen potencial, vklop pa je izveden s stikalom pred vhodom v vezje.



Fotografija ohišja z elektroniko za krmiljenje motorjev in napajalnim vezjem



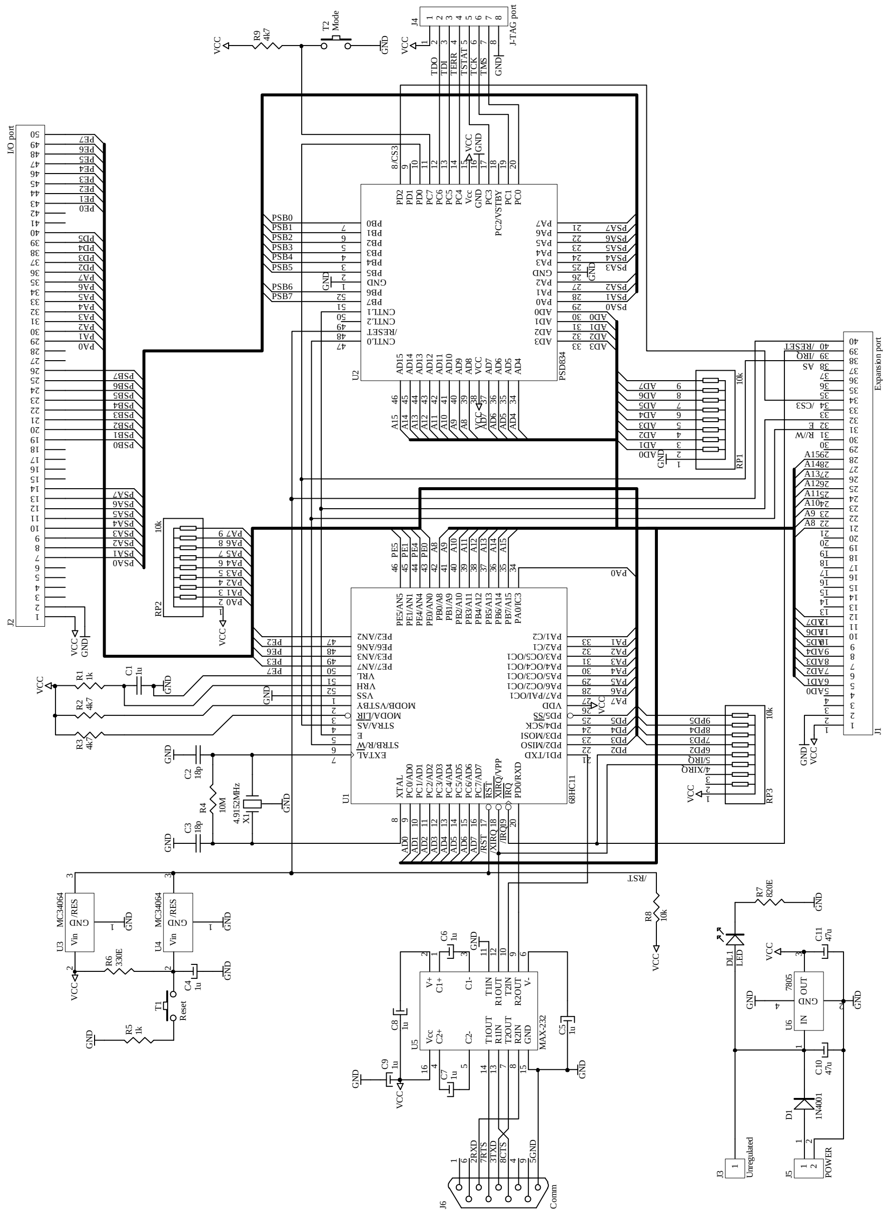
Fotografija kontrolnega modula

8 Priloge

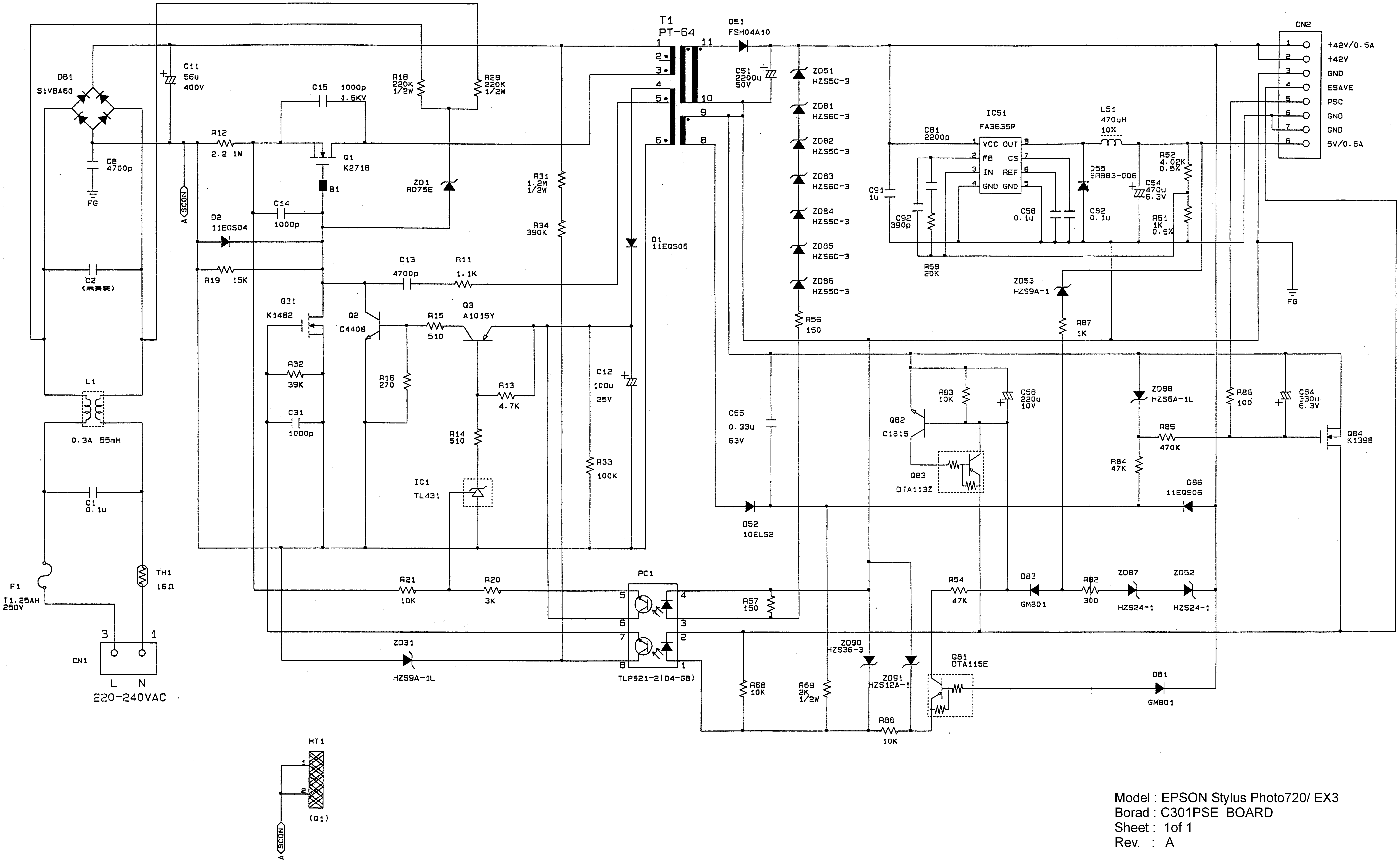
Električna shema procesorske plošče
Električna sehema tisalniškega napajalnika
Datasheet krmilnika koračnega motorja SLA7062
Datasheet končnega opto-senzorja

9 Reference

http://en.wikipedia.org/wiki/Stepper_motor
http://www.eio.com/stepindx.htm



Slika 17: Celotna shema mikrokrmilniške enote



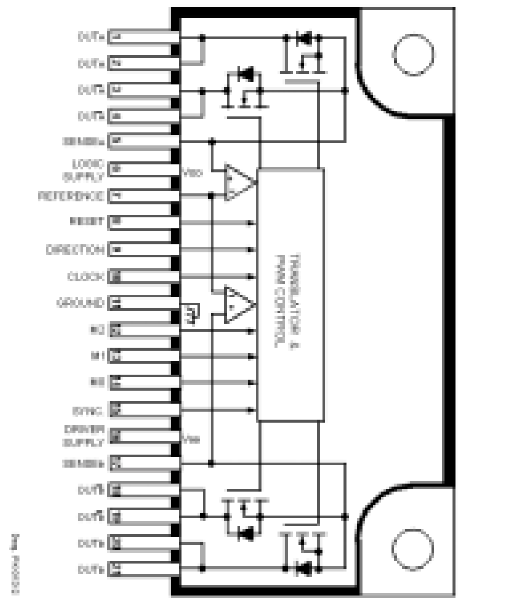
Model : EPSON Stylus Photo720/ EX3
Borad : C301PSE BOARD
Sheet : 1of 1
Rev. : A

PRELIMINARY INFORMATION
(subject to change without notice)
September 24, 2003

SLA7060M THRU SLA7062M

Data Sheet **28210.10**

UNIPOLAR STEPPER-MOTOR TRANSLATOR/DRIVERS



Absolute Maximum Ratings

Driver Supply Voltage, V_{BB} .... **46 V**
Load Supply Voltage, V_M .... **46 V**
Output Current, I_O
SLA7060M .... **1.0 A***
SLA7061M .... **2.0 A***
SLA7062M .... **3.0 A***
Logic Supply Voltage, V_{DD} .... **7.0 V**
Logic Input Voltage Range,
V_I .... **-0.3 V to V_{DD}+ 0.3 V**
Sense Voltage, V_S .... **±2.0 V†**
Reference Input Voltage Range,
V_{REF} .... **-0.3 V to V_{DD}+ 0.3 V**
Package Power Dissipation,
P_D .... **See Graph**
Junction Temperature, T_J............. **+150°C**
Operating Temperature Range,
T_A .... **-20°C to +85°C**
Storage Temperature Range,
T_S .... **-30°C to +150°C**

* Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or junction temperature.
† Internal filtering provides protection against transients during the first 1 µs of the current-sense pulse.

Combining low-power CMOS logic with high-current, high-voltage power FET outputs, the Series SLA7060M translator/drivers provide complete control and drive for a two-phase unipolar stepper motor with internal fixed off time and pulse-width modulation (PWM) control of the output current in a power multi-chip module (PMCM™). There are no phase-sequence tables, high-frequency control lines, or complex interfaces to program.

The CMOS logic section provides the sequencing logic, direction, control, synchronous/asynchronous PWM operation, and a “sleep” function. The minimum CLOCK input is an ideal fit for applications where a complex µP is unavailable or overburdened. TTL or LSTTL may require the use of appropriate pull-up resistors to ensure a proper input-logic high. For PWM current control, the maximum output current is determined by the user’s selection of a reference voltage and sensing resistor. The NMOS outputs are capable of sinking up to 1, 2, or 3 A (depending on device) and withstanding 46 V in the off state. Clamp diodes provide protection against inductive transients. Special power-up sequencing is not required.

Half-, quarter-, eighth-, and sixteenth-step operation are externally selectable for the SLA7060/61/62M. Half-step excitation alternates between the one-phase and two-phase modes ($\overline{A}B$-$\overline{B}$-$A\overline{B}$-A-AB-B-$\overline{A}B$-$\overline{A}$), providing an eight-step sequence.

The Series SLA7060M is supplied in a 21-pin single in-line power-tab package with leads formed for vertical mounting (suffix LF2102). The tab is at ground potential and needs no insulation. For high-current or high-frequency applications, external heat sinking may be required. This device is rated for continuous operation between -20°C and +85°C.

Features

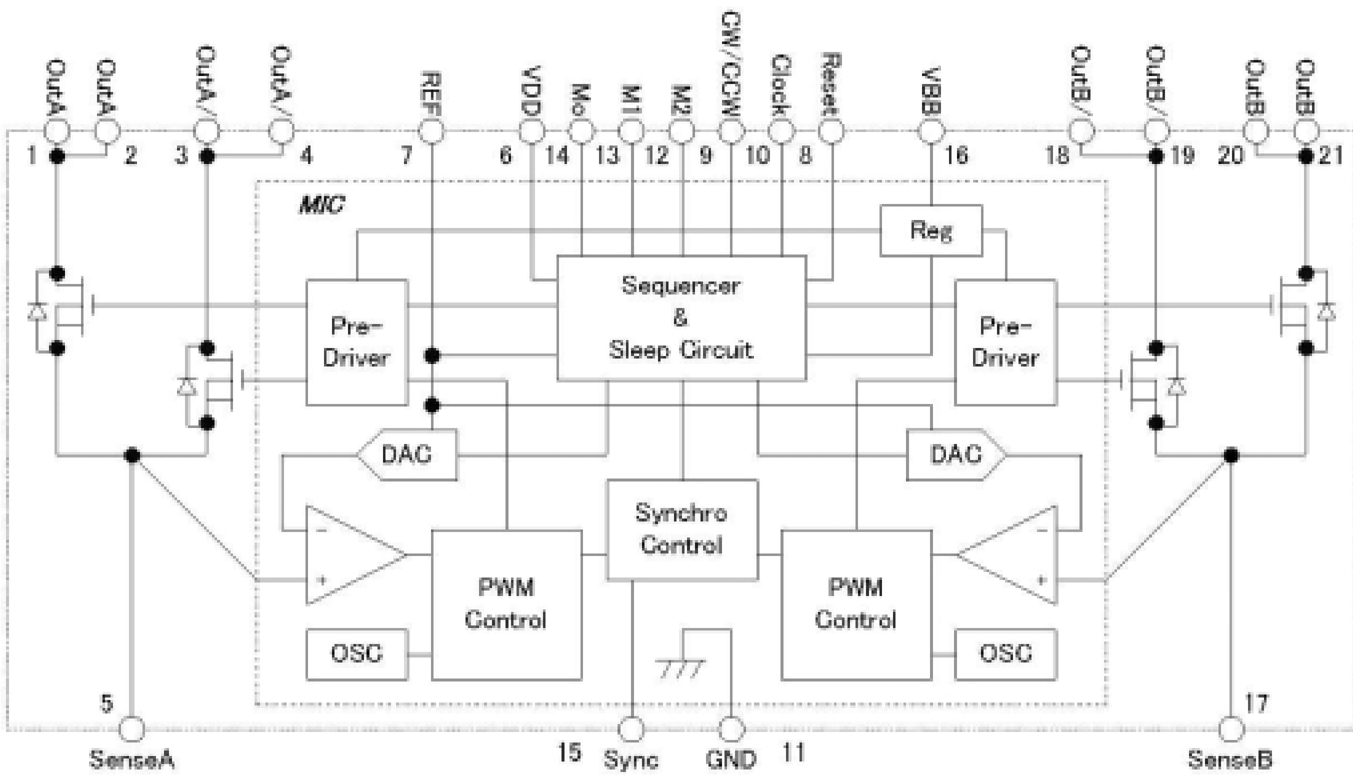
- To 3 A Output Rating
- Internal Sequencer for Microstepping Operation
- PWM Constant-Current Motor Drive
- Cost-Effective, Multi-Chip Solution
- 100 V, Avalanche-Rated NMOS
- Low $r_{DS(on)}$ NMOS Outputs
- Advanced, Improved Body Diodes
- Inputs Compatible with 3.3 V or 5 V Control Signals
- Sleep Mode
- Internal Clamp Diodes

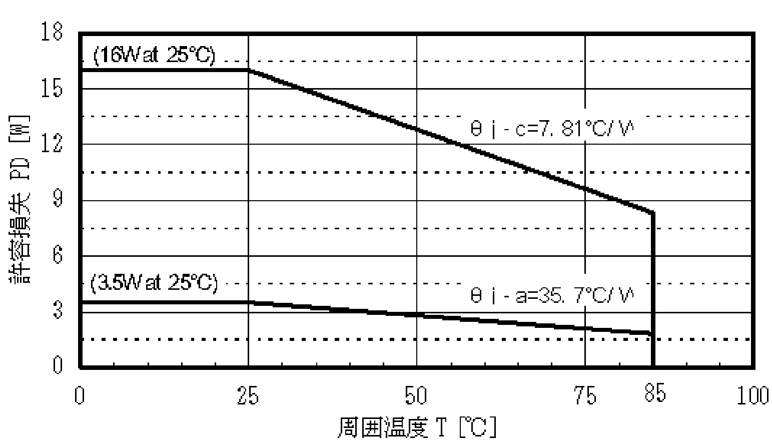
Always order by complete part number, e.g., **SLA7060MLF2102** .

SanKen

Allegro® MicroSystems, Inc.

Functional block diagram





Recommended operating conditions

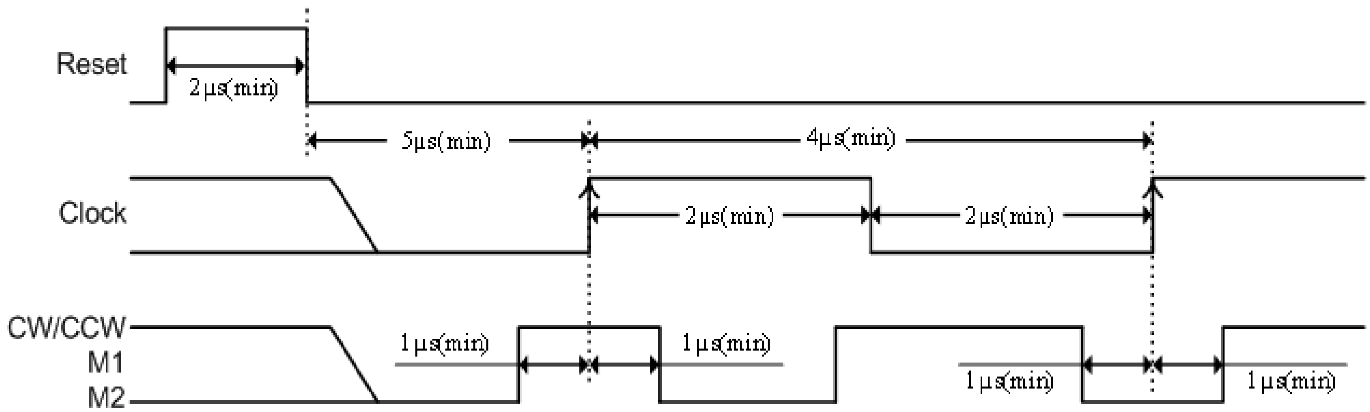
Load Supply Voltage, V_{BB} .... **10 to 44 V**
Logic Supply Voltage, V_{DD} .... **3.0 V to 5.5 V**
Reference Input Voltage, V_{REF} .... **0.1 V to 1.0 V**
Tab Temperature (no heat sink), T_T................. **<90°C**

Allegro MicroSystems, Inc.
115 Northeast Cutoff, Box 15036
Worcester, Massachusetts 01615-0036 (508) 853-5000

Electrical characteristics: unless otherwise noted at T_A = +25°C, V_{BB} = 24 V, V_{DD} = 5.0 V.

Characteristic	Symbol	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Output drivers						
Driver Supply Volt. Range	V_{BB}	Operating	10	—	44	V
Drain-Source Breakdown	$V_{(BR)DS}$	V_{BB} = 44 V, I_D = 1 mA	100	—	—	V
Output On Resistance	$r_{DS(on)}$	SLA7060M, I_O = 1.0 A	—	700	850	mΩ
		SLA7061M, I_O = 2.0 A	—	250	400	mΩ
		SLA7062M, I_O = 3.0 A	—	180	240	mΩ
Body Diode Forward Volt.	V_F	SLA7060M, I_F = 1.0 A	—	0.85	1.1	V
		SLA7061M, I_F = 2.0 A	—	0.95	TBD	V
		SLA7062M, I_F = 3.0 A	—	0.95	TBD	V
Driver Supply Current	I_{BB}		—	—	15	mA
		V_{REF} > 2.0 V (sleep mode)	—	—	100	µA
Control logic						
Logic Supply Volt. Range	V_{DD}	Operating	3.0	5.0	5.5	V
Logic Input Voltage	V_{IH}		$0.75V_{DD}$	—	—	V
	V_{IL}		—	—	$0.25V_{DD}$	V
Logic Input Current	I_{IH}		—	±1.0	—	µA
	I_{IL}	CLOCK, RESET, CW/CCW, and SYNC.	—	±1.0	—	µA
		M1 and M2	-25	-50	-75	µA
Max. Clock Frequency	f_{clk}		250*	—	—	kHz
PWM Off Time	t_{off}	70 to 100%I_{trip}max	—	12	—	µs
		38 to 64%I_{trip}max	—	9.0	—	µs
		9 to 30%I_{trip}max	—	7.0	—	µs
PWM Min. On Time	$t_{on(min)}$		—	1.8	—	µs
Ref. Input Voltage Range	V_{REF}	Operating	0	—	1.5	V
		Sleep mode	2.0	—	V_{DD}	V
Ref. Input Current	I_{REF}		—	±10	—	µA
Monitor Output Voltage	V_{MoH}		V_{DD} - 1.25	—	—	V
	V_{MoL}		—	—	1.25	V
Monitor Output Current	I_{Mo}		—	—	±3.0	mA
Sense Voltage	V_S	Trip point at 100% I_O	$0.95V_{REF}$	V_{REF}	$1.05V_{REF}$	V
Sense Input Current	I_{SENSE}		—	±10	—	µA
Propagation Delay Time	t_{PLH}	Clock rising edge to output on	—	2.0	—	µs
	t_{PHL}	Clock rising edge to output off	—	1.5	—	µs
Logic Supply Current	I_{DD}		—	—	4.0	mA

Typical values are given for circuit design information only.
*Operation at a clock frequency greater than the specified minimum value is possible but not warranted.



Logic input timing

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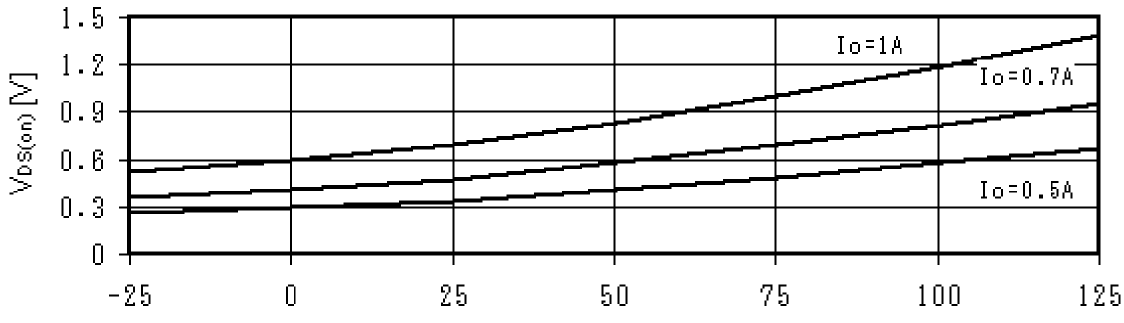
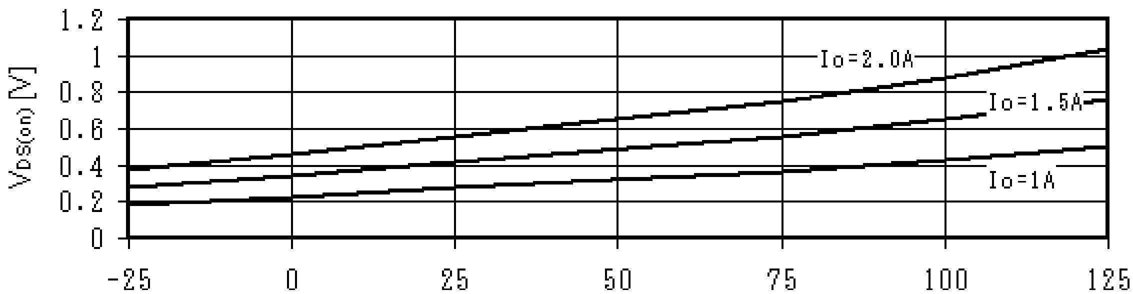
Typical MOSFET characteristics

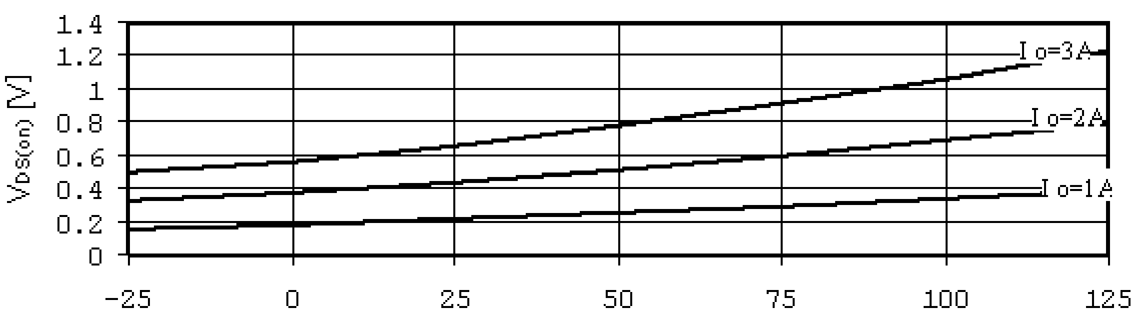
SLA7060M



SLA7061M

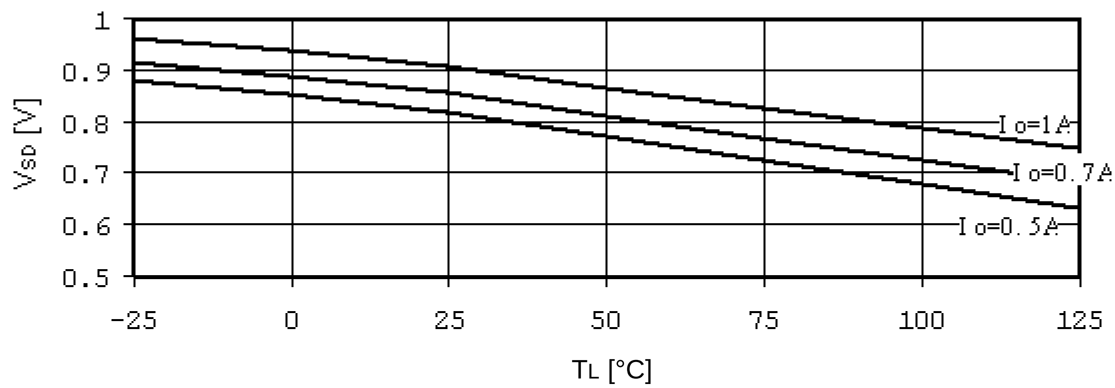


SLA7062M

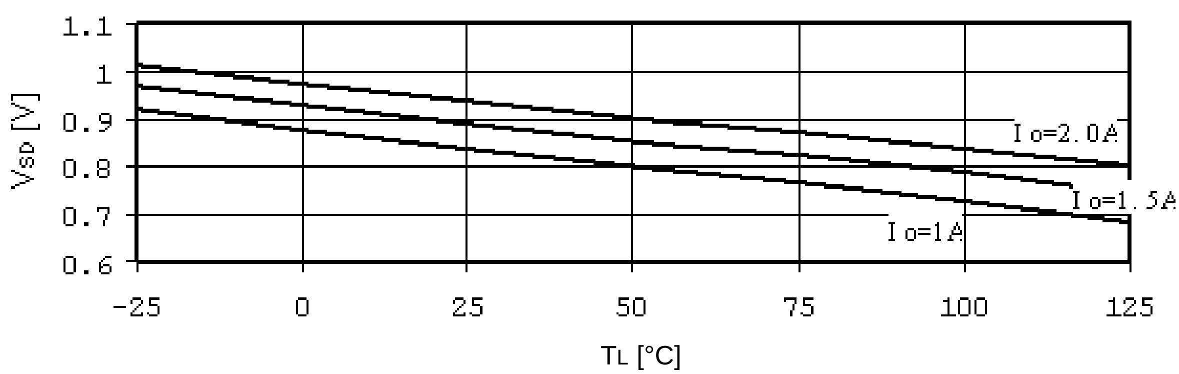


Typical body diode characteristics

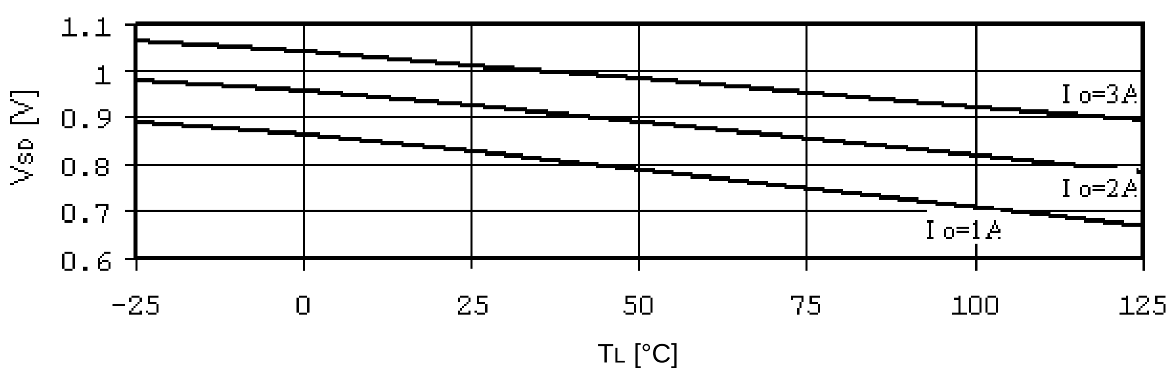
SLA7060M



SLA7061M



SLA7062M



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Functional description

Device operation. These devices are complete microstepping motor drivers with built in translator for easy operation with minimal control lines. They are designed to operate unipolar stepper motors in half-, quarter-, eighth-, and sixteenth-step modes. The current in each of the four outputs, all n-channel DMOS, is regulated with fixed off time pulse-width modulated (PWM) control circuitry. The current at each step is set by the value of an external current-sense resistor (R_S), a reference voltage (V_{REF}), and the DAC's output voltage controlled by the output of the translator.

At V_{DD} power up, or reset, the translator sets the DACs to the home state (see figures for reset conditions). When a step command signal occurs on the CLOCK input the translator automatically sequences the DACs to the next level (see table 2 for the current level sequence). The microstep resolution is set by inputs M1 and M2 as shown in table 1.

RESET input. The RESET input sets the translator to a predefined home state (see table 2) and turns off all of the DMOS outputs. The monitor output (MO) goes low and all STEP inputs are ignored until the RESET input goes low. A low-pass filter is integrated into the reset circuit; therefore a 5 µs delay is required between the falling edge of the RESET input and the rising edge of the CLOCK input.

Monitor output (MO). A logic output indicator of the initial/home state of the translator (45°). At power up the translator is reset to the home state (phase A and phase B output currents are both at the half-step position or 70.7%). This output is also high at the 135°, 225°, and 315° positions.

CLOCK (step) input. A low-to-high transition on the clock input sequences the translator, which controls the input to the DACs and advances the motor one increment. The size of the increment is determined by the state of inputs M1 and M2 (see table 1). The hold state is done by stopping the CLOCK input regardless of the input level

Microstep select (M1 and M2). These logic-level inputs set the translator step mode per table 1. Changes to these inputs do not take effect until the rising edge of the clock input.

Direction (CW/CCW) input. This logic-level input sets the translator step direction. Changes to this input do not take effect until the rising edge of the clock input.

Internal PWM current control. Each pair of outputs is controlled by a fixed off-time (7 to 12 µs, depending on step) PWM current-control circuit that limits the load current to a desired value (I_{TRIP}). Initially, an output is enabled and current flows through the motor winding and R_S. When the voltage across the current-sense resistor equals the DAC output voltage, the current-sense comparator resets the PWM latch, which turns off the driver for the fixed off time during which the load inductance causes the current to recirculate for the off time period. The driver is then re-enabled and the cycle repeats.

Synchronous operation mode. This function prevents occasional motor noise during a "hold" state, which normally results from asynchronous PWM operation of both motor phases. A logic high at the SYNC input is synchronous operation; a logic low is asynchronous operation. The use of synchronous operation during normal stepping is not recommended because it produces less motor torque and can cause motor vibration due to stair-case current.

Sleep mode. Applying a voltage greater than 2 V to the REF pin disables the outputs and puts the motor in a free state (coast). This function is used to minimize power consumption when not in use. Although it disables much of the internal circuitry including the output MOSFETs and regulator, the sequencer/translator circuit is active and therefore a microcontroller can set the step starting point for the next operation during the sleep mode. When coming out of sleep mode, wait 100 µs before issuing a step command to allow the internal circuitry to stabilize.

Table 1. Step Modes

Input M1	Input M2	Step Mode
H	H	Half Step
H	L	Quarter Step
L	H	Eighth Step
L	L	Sixteenth Step

Table 2. Step Sequencing

(CW/CCW = L)

Half Step #	Quarter Step #	Eighth Step #	Sixteenth Step #	Phase A or A\ Current [% I_{trip}max]	Phase B or B\ Current [% I_{trip}max]	Step Angle
0	0	0	0	70.7	70.7	45*
			1	77.3	63.4	
		1	2	83.1	55.5	
			3	88.2	47.1	
	1	2	4	92.4	38.2	67.5
			5	95.7	29.0	
		3	6	98.1	19.5	
			7	100	9.8	
1	2	4	8	100	0	90
			9	100	-9.8	
		5	10	98.1	-19.5	
			11	95.7	-29.0	
	3	6	12	92.4	-38.2	102.5
			13	88.2	-47.1	
		7	14	83.1	-55.5	
			15	77.3	-63.4	
2	4	8	16	70.7	-70.7	135†
			17	63.4	-77.3	
		9	18	55.5	-83.1	
			19	47.1	-88.2	
	5	10	20	38.2	-92.4	157.5
			21	29.0	-95.7	
		11	22	19.5	-98.1	
			23	9.8	-100	
3	6	12	24	0	-100	180
			25	-9.8	-100	
		13	26	-19.5	-98.1	
			27	-29.0	-95.7	
	7	14	28	-38.2	-92.4	202.5
			29	-47.1	-88.2	
		15	30	-55.5	-83.1	
			31	-63.4	-77.3	
4	8	16	32	-70.7	-70.7	225†
			33	-77.3	-63.4	
		17	34	-83.1	-55.5	
			35	-88.2	-47.1	
	9	18	36	-92.4	-38.2	247.5
			37	-95.7	-29.0	
		19	38	-98.1	-19.5	
			39	-100	-9.8	
5	10	20	40	-100	0	270
			41	-100	9.8	
		21	42	-98.1	19.5	
			43	-95.7	29.0	
	11	22	44	-92.4	38.2	292.5
			45	-88.2	47.1	
		23	46	-83.1	55.5	
			47	-77.3	63.4	
6	12	24	48	-70.7	70.7	315†
			49	-63.4	77.3	
		25	50	-55.5	83.1	
			51	-47.1	88.2	
	13	26	52	-38.2	92.4	337.5
			53	-29.0	95.7	
		27	54	-19.5	98.1	
			55	-9.8	100	
7	14	28	56	0	100	360
			57	9.8	100	
		29	58	19.5	98.1	
			59	29.0	95.7	
	15	30	60	38.2	92.4	22.5
			61	47.1	88.2	
		31	62	55.5	83.1	
			63	63.4	77.3	
8	16	32	64	70.7	70.7	45*

* Home state; MO output high. † MO output high.

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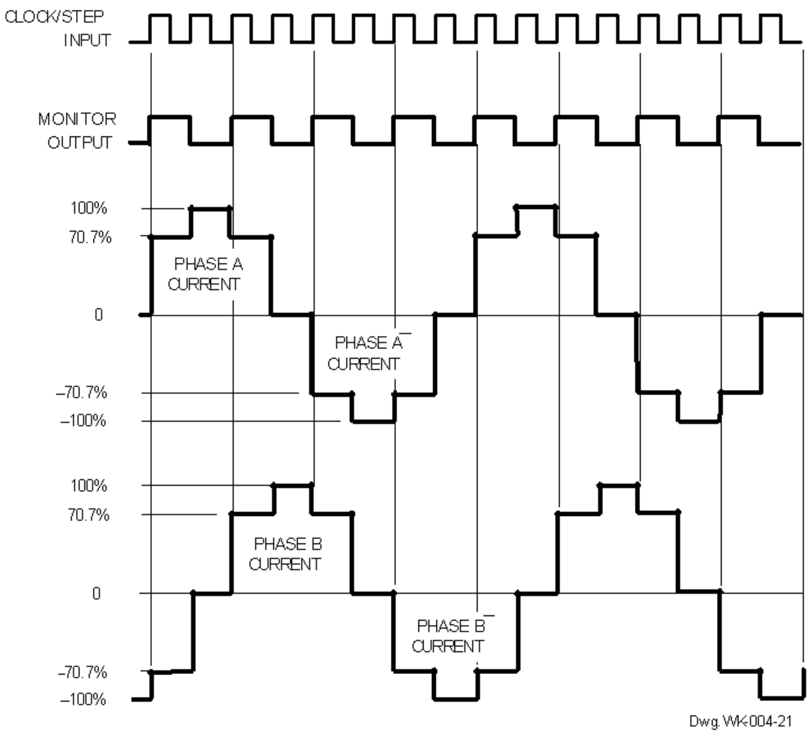
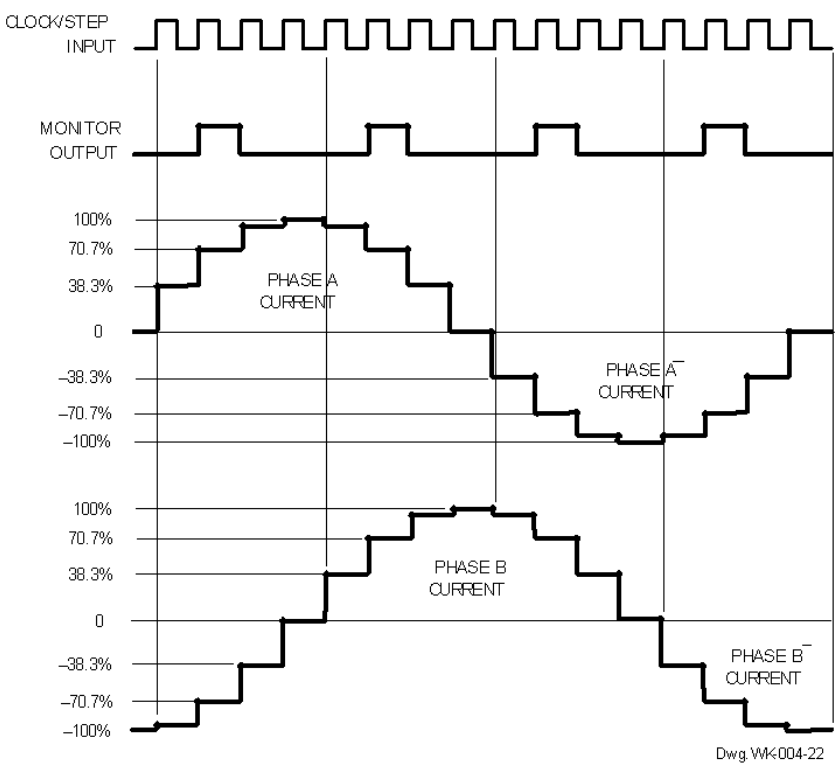
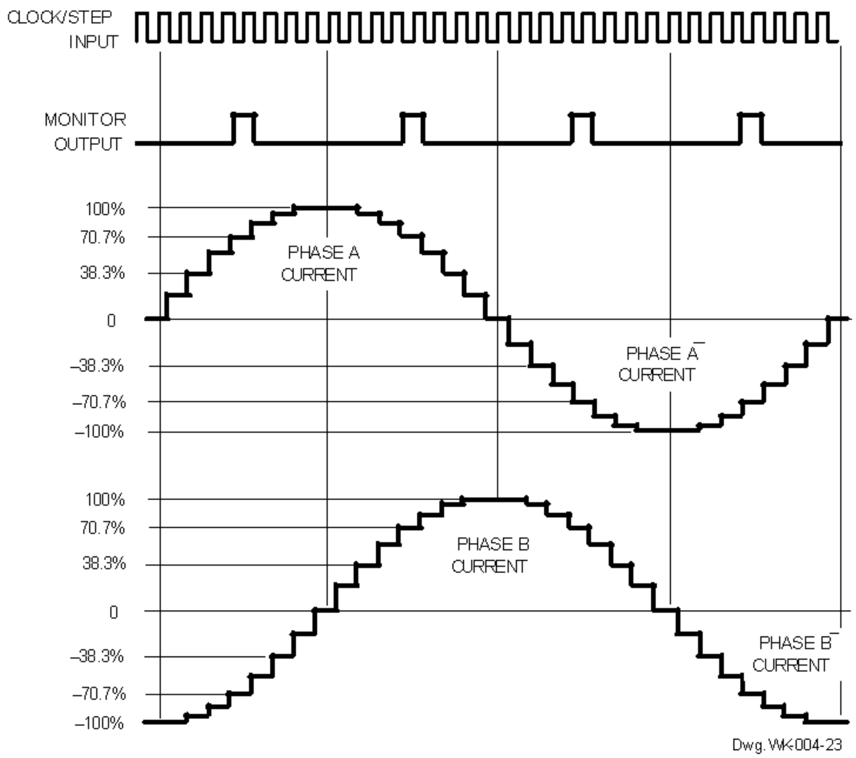


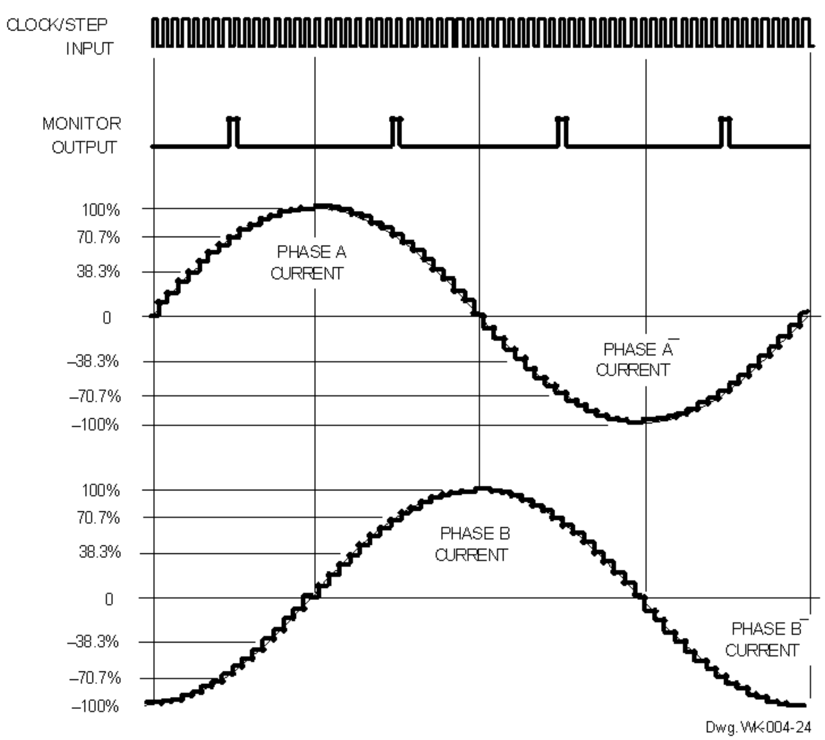
Half-step output current waveshapes. For illustrative purposes, phase A\ or B\ current (unipolar drive) is shown as negative current.



Quarter-step output current waveshapes. For illustrative purposes, phase A\ or B\ current (unipolar drive) is shown as negative current.



Eighth-step output current waveshapes. For illustrative purposes, phase A\ or B\ current (unipolar drive) is shown as negative current.



Sixteenth-step output current waveshapes. For illustrative purposes, phase A\ or B\ current (unipolar drive) is shown as negative current.

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Applications information

Layout.

The printed wirting board should use a heavy ground plane.

For optimum electrical and thermal performance, the driver should be soldered directly into the board.

The driver supply terminal, VBB, should be decoupled with an electrolytic capacitor (>47 µF is recommended) placed as close to the device as possible.

To avoid problems due to capacitive coupling of the high dv/dt switching transients, route the high-level, output traces away from the sensitive, low-level logic traces. Always drive the logic inputs with a low source impedance to increase noise immunity.

Grounding. A star ground system located close to the driver is recommended. The logic supply return and the driver supply return should be connected together at only a single point — the star ground.

Logic supply voltage, V_{DD}. Transients at this terminal should be held to less than 0.5 V to avoid malfunctioning operation. Both V_{BB} and V_{DD} may be turned on or off separately.

Logic inputs. Unused logic inputs (CW/CCW, M1, M2, RESET, or SYNC) must be connected to either ground or the logic supply voltage.

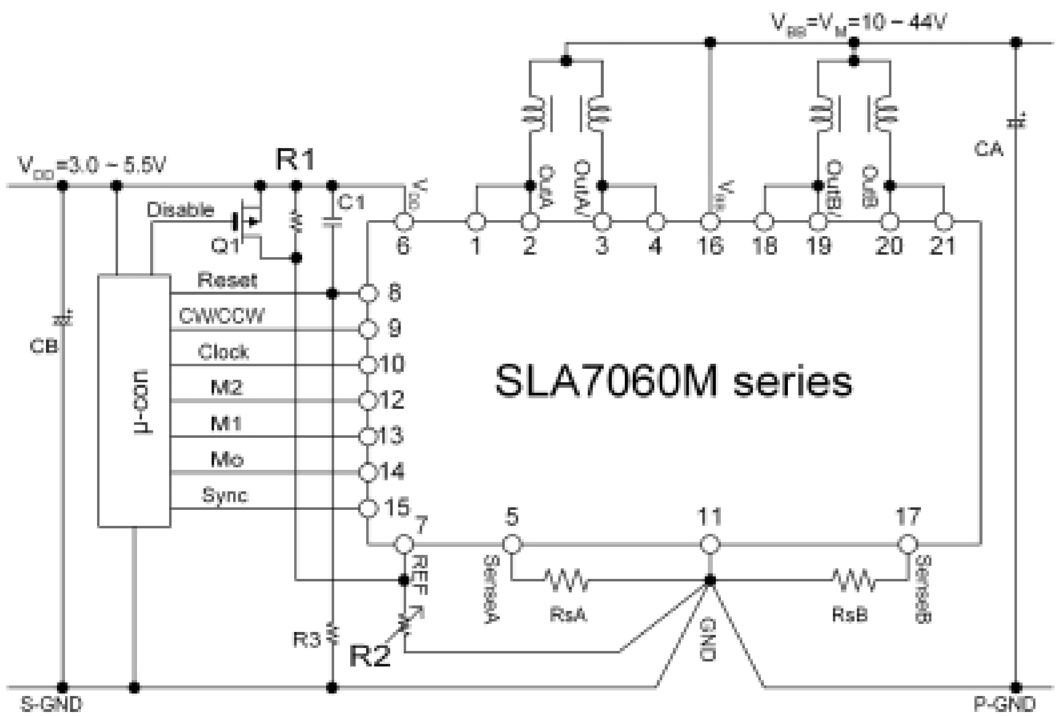
Current sensing. To minimize inaccuracies caused by ground-trace IR drops in sensing the output current level, the current-sense resistors, R_S, should have an independent ground return to the star ground of the device. This path should be as short as possible. For low-value sense resistors, the IR drops in the printed wiring board sense resistor's traces can be significant and should be taken into account. The use of sockets should be avoided as they can introduce variation in R_S due to their contact resistance.

PWM current control. The maximum value of current limiting (I_{TRIP}) is set by the selection of R_S and the voltage at the REF input with a transconductance function approximated by:

$$I_{TRIP} = V_{REF}/R_S$$

The required V_{REF} should not be less than 0.1 V. If it is, R_S should be increased for a proportionate increase in V_{REF}.

RS = 0.1 Ω to 2 Ω
R1 = 10 kΩ
R2 = 5.1 kΩ
R3 = 10 kΩ
CA = 100 µF, 50 V
CB = 10 µF, 10 V
C1 = 0.1 µF



Applications Information (cont'd)

Reference voltage. In the Typical Application shown, resistors R_1 and R_2 set the reference voltage as:

$$V_{REF} = (V_{DD} \times R_2)/(R_1 + R_2)$$

The trimming of R_2 allows for the resistor tolerances and REF input current. The sum of R_1+R_2 should be less than 50 kΩ to minimize the effect of I_{REF}.

Minimum output current. The Series SLA7060M uses fixed off-time PWM current control. Due to internal logic and switching delays, the actual load current peak will be slightly higher than the calculated I_{TRIP} value (especially for low-inductance loads). These delays, plus the minimum recommended V_{REF}, limit the minimum value the current-control circuitry can regulate. An application with this device should maintain continuous PWM control in order to obtain optimum torque out of the motor. The boundary of the load current ($I_{O(min)}$) between continuous and discontinuous operation is:

$$I_{O(min)} = [(V_M + V_{SD})/R_m] \times [(1/e^{t_{off}/[R_m \times L_m]}) - 1]$$

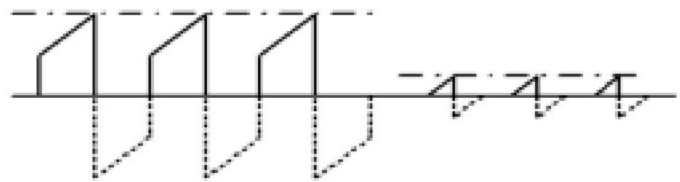
where V_M = load supply voltage
V_F = body diode forward voltage
R_m = motor winding resistance
t_{off} = PWM off time
L_m = motor winding inductance

To produce zero current in a motor, the REF input should be pulled above 2 V, turning off all drivers.

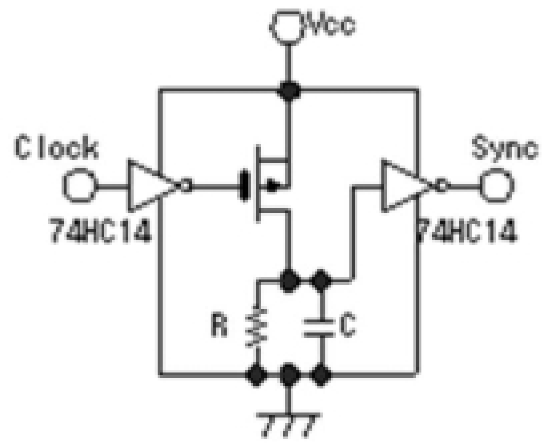
Synchronous operation mode. If an external signal is not available to control the synchronous operation mode, a simple circuit can keep the SYNC input low while the CLOCK input is active; the SYNC input will go high (synchronous operation) when the CLOCK input stays low ("hold"). The RC time constant determines the sync trransition timing.

NOTE –The use of this function except at 0, 70.7, or 100%I_{trip}max (half-step positions 0 through 8) is not recommended.

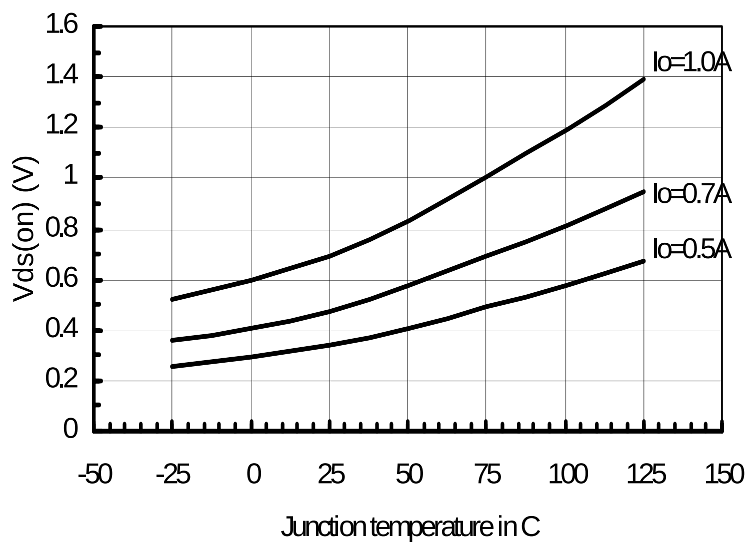
Temperature effects on FET outputs. Analyzing safe, reliable operation includes a concern for the relationship of NMOS on resistance to junction temperature. Device package power calculations must include the increase in on resistance (producing higher on voltages)



Continuous mode **Discontinuous mode**



Sync. signal generator



Normalized FET on resistance

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Applications Information (cont'd)

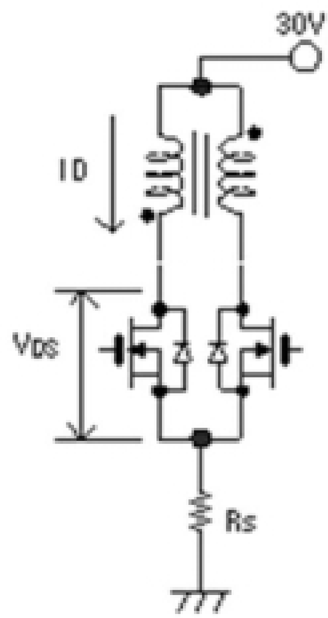
caused by increased operating junction temperatures. The figure provides a normalized on-resistance curve, and all thermal calculations should consider increases from the given +25°C limits, which may be caused by internal heating during normal operation.

These power MOSFET outputs feature an excellent combination of fast switching, ruggedized device design, low on resistance, and cost effectiveness.

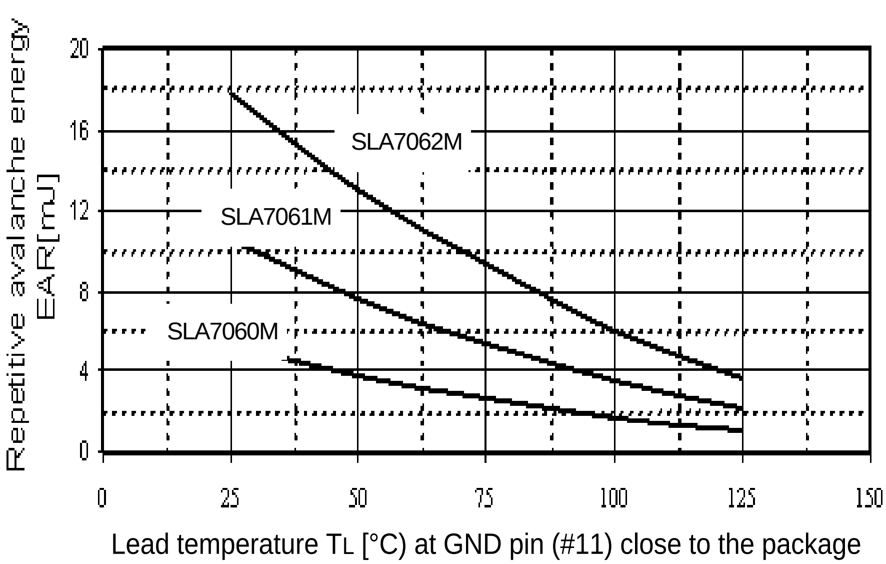
Avalanche energy capability. There is a surge voltage expected when the output MOSFET turns off, and this voltage may exceed the MOSFET breakdown voltage ($V_{(BR)DS}$). However, the MOSFETs are avalanche type and as long as the energy ($E_{(AV)}$), which is imposed on the MOSFET by the surge voltage, is less than the maximum allowable value, it is considered to be within its safe operating area. Note that the maximum allowable avalanche energy is reduced as a function of temperature.

In application, the avalanche energy ($E_{(AV)}$) dissipated by the MOSFET is approximated as

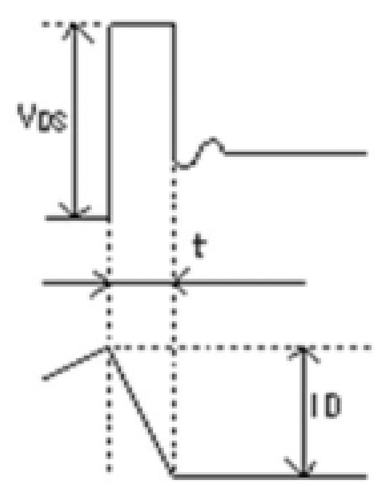
$$E_{(AV)} = V_{DS(AV)} \times 0.5 \times I_D \times t$$



Output circuit for avalanche energy calculations



Allowable avalanche energy



Waveforms during avalanche breakdown

Terminal list

Pin	Terminal Name	Terminal Description
1, 2	OUTA	Driver outputs for phase A
3, 4	OUTA\	Driver outputs for phase A\
5	SENSEA	Phase A current sense
6	VDD	Logic power supply, V_{DD}
7	REF	Current set & “sleep” control
8	RESET	Logic control input
9	CW/CCW	Forward/reverse logic control input
10	CLOCK	Step clock input
11	GND	Supply negative return
12	M2	Step mode logic control input
13	M1	Step mode logic control input
14	MO	Monitor logic output
15	SYNC	Synchronous PWM control input
16	VBB	Driver power supply, V_{BB}
17	SENSEB	Phase B current sense
18, 19	OUTB\	Driver outputs for phase B\
20, 21	OUTB	Driver outputs for phase B

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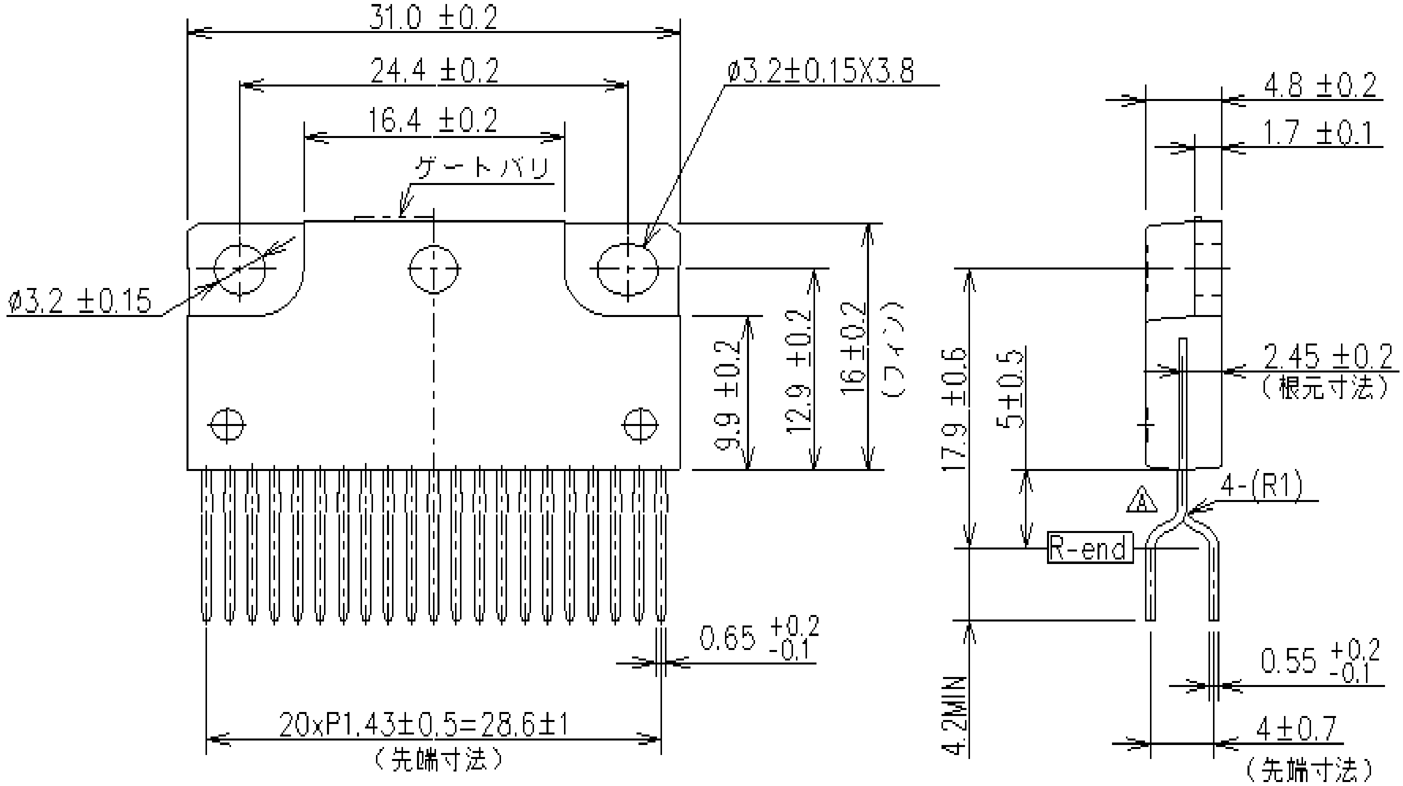
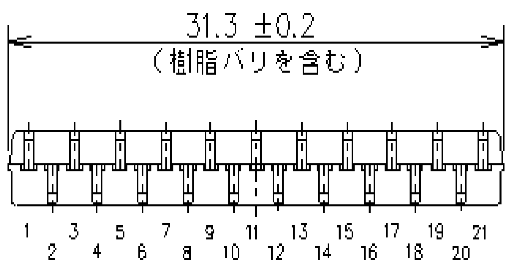
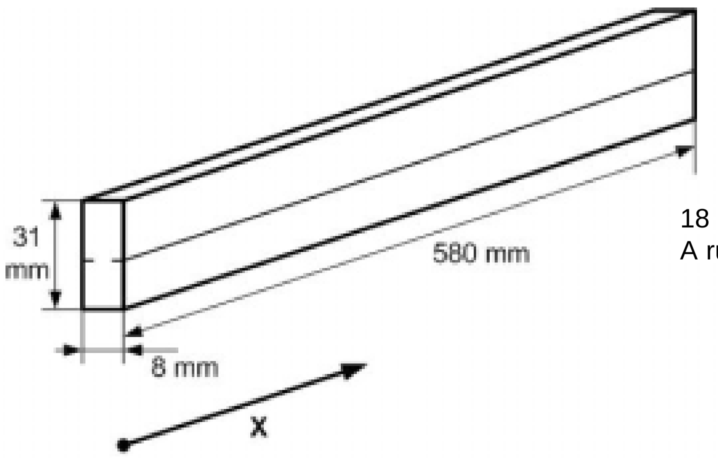
SLA706xMLF2102
Dimensions in millimeters



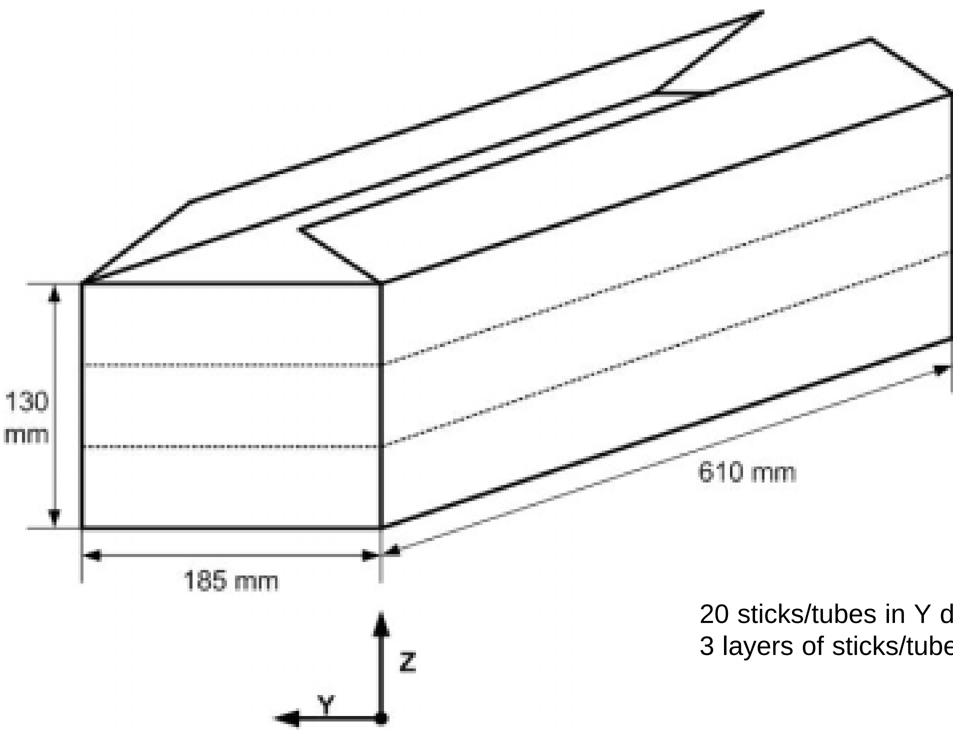


NOTES: 1. Exact body and lead configuration at vendor’s option within limits shown.
2. Lead spacing tolerance is non-cumulative.
3. Recommended mounting hardware torque: 0.490 - 0.822 Nm.
4. Recommended use of metal-oxide-filled, alkyl-degenerated oil-base silicone grease: Dow Corning SC102, Toshiba YG6260, Shin-Etsu G746, or equivalent.

Packing information



18 devices per stick/tube.
A rubber stopper is provided at each end of the stick/tube.



20 sticks/tubes in Y direction;
3 layers of sticks/tubes in Z direction = 1080 devices per box.

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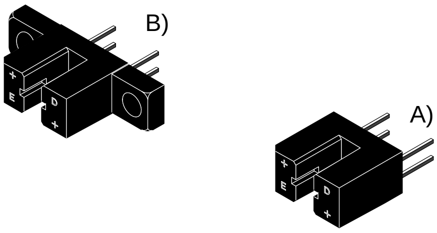
Transmissive Optical Sensor with Phototransistor Output

Description

This device has a compact construction where the emitting-light sources and the detectors are located face-to-face on the same optical axis. The operating wavelength is 950 nm. The detector consists of a phototransistor.



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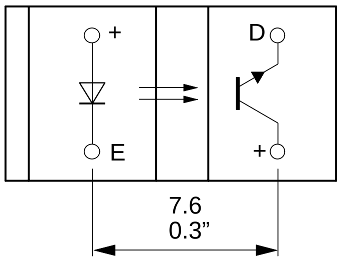
Applications

- Contactless optoelectronic switch, control and counter

Features

- Compact construction
- No setting efforts
- Polycarbonate case protected against ambient light
- 2 case variations
- 3 different apertures
- CTR selected in groups (regarding fourth number of type designation)

95 10796



Top view

Order Instruction

Ordering Code	Resolution (mm) / Aperture (mm)	Remarks
TCST1103A)	0.6 / 1.0	No mounting flags
TCST2103B)		With two mounting flags
TCST1202A)	0.4 / 0.5	No mounting flags
TCST2202B)		With two mounting flags
TCST1300A)	0.2 / 0.25	No mounting flags
TCST2300B)		With two mounting flags

Absolute Maximum Ratings

Input (Emitter)

Parameter	Test Conditions	Symbol	Value	Unit
Reverse voltage		V_R	6	V
Forward current		I_F	60	mA
Forward surge current	$t_p \leq 10\ \mu s$	I_{FSM}	3	A
Power dissipation	$T_{amb} \leq 25^\circ C$	P_V	100	mW
Junction temperature		T_j	100	°C

Output (Detector)

Parameter	Test Conditions	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	70	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	100	mA
Collector peak current	$t_p/T = 0.5$, $t_p \leq 10$ ms	I_{CM}	200	mA
Power dissipation	$T_{amb} \leq 25^\circ C$	P_V	150	mW
Junction temperature		T_j	100	°C

Coupler

Parameter	Test Conditions	Symbol	Value	Unit
Total power dissipation	$T_{amb} \leq 25^\circ C$	P_{tot}	250	mW
Operating temperature range		T_{amb}	–55 to +85	°C
Storage temperature range		T_{stg}	–55 to +100	°C
Soldering temperature	2 mm from case, $t \leq 5$ s	T_{sd}	260	°C

Electrical Characteristics (T_{amb} = 25°C)

Input (Emitter)

Parameter	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
Forward voltage	I_F = 60 mA	V_F		1.25	1.6	V
Junction capacitance	V_R = 0, f = 1 MHz	C_j		50		pF

Output (Detector)

Parameter	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	70			V
Emitter collector voltage	I_E = 10 μA	V_{ECO}	7			V
Collector dark current	V_{CE} = 25 V, I_F = 0, E = 0	I_{CEO}			100	nA

Coupler

Parameter	Test Conditions	Type	Symbol	Min.	Typ.	Max.	Unit
Current transfer ratio	V_{CE} = 5 V, I_F = 20 mA	TCST1103, TCST2103	CTR	10	20		%
		TCST1202, TCST2202	CTR	5	10		%
		TCST1300, TCST2300	CTR	1.25	2.5		%
Collector current	V_{CE} = 5 V, I_F = 20 mA	TCST1103, TCST2103	I_C	2	4		mA
		TCST1202, TCST2202	I_C	1	2		mA
		TCST1300, TCST2300	I_C	0.25	0.5		mA
Collector emitter saturation voltage	I_F = 20 mA, I_C = 1 mA	TCST1103, TCST2103	V_{CEsat}			0.4	V
	I_F = 20 mA, I_C = 0.5 mA	TCST1202, TCST2202	V_{CEsat}			0.4	V
	I_F = 20 mA, I_C = 0.1 mA	TCST1300, TCST2300	V_{CEsat}			0.4	V
Resolution, path of the shutter crossing the radiant sensitive zone	I_{Crel} = 10 to 90%	TCST1103, TCST2103	s		0.6		mm
		TCST1202, TCST2202	s		0.4		mm
		TCST1300, TCST2300	s		0.2		mm

Switching Characteristics

Parameter	Test Conditions	Symbol	Typ.	Unit
Turn-on time	V_S = 5 V, I_C = 2 mA, R_L = 100 Ω (see figure 1)	t_{on}	10.0	μs
Turn-off time		t_{off}	8.0	μs

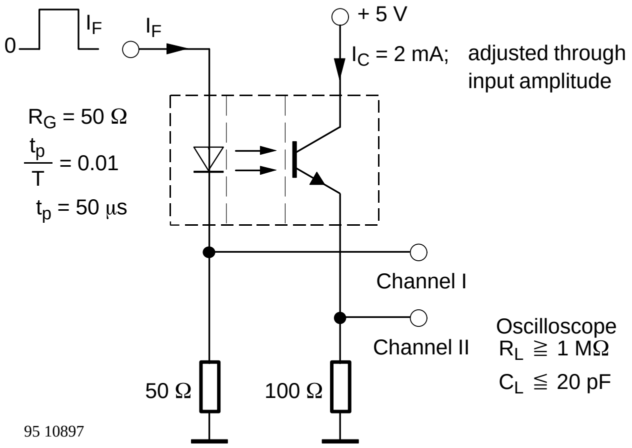
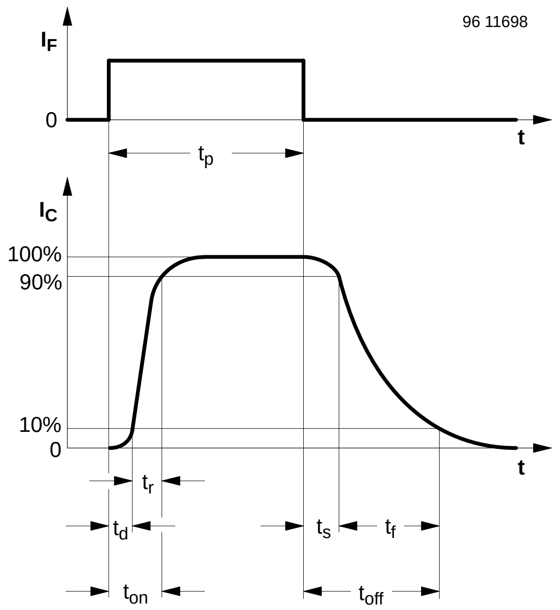


Figure 1. Test circuit, saturated operation



t_p	pulse duration	t_s	storage time
t_d	delay time	t_f	fall time
t_r	rise time	t_{off} (= t_s + t_f)	turn-off time
t_{on} (= t_d + t_r)	turn-on time		

Figure 2. Switching times

Typical Characteristics (T_{amb} = 25°C, unless otherwise specified)

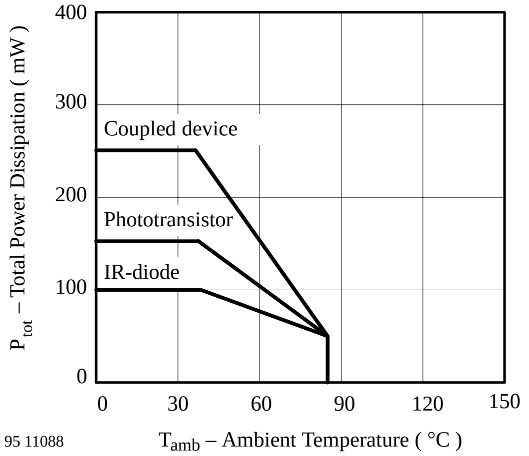


Figure 3. Total Power Dissipation vs. Ambient Temperature

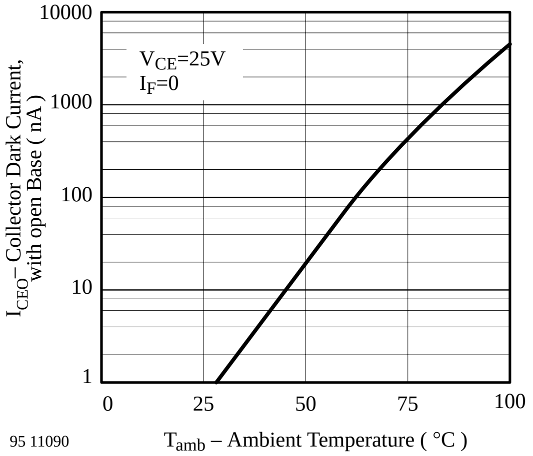


Figure 6. Collector Dark Current vs. Ambient Temperature

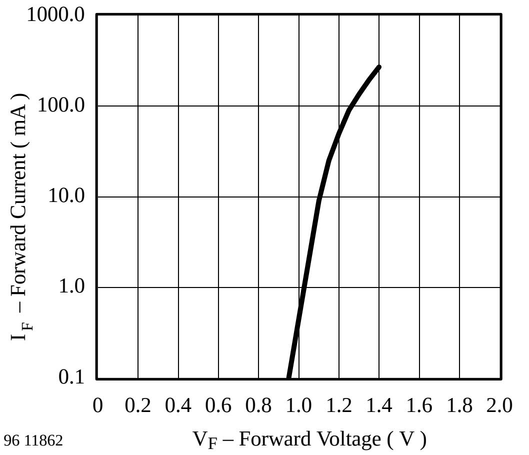


Figure 4. Forward Current vs. Forward Voltage

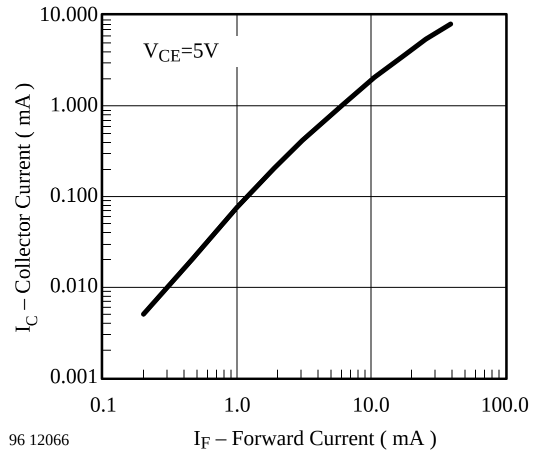


Figure 7. Collector Current vs. Forward Current

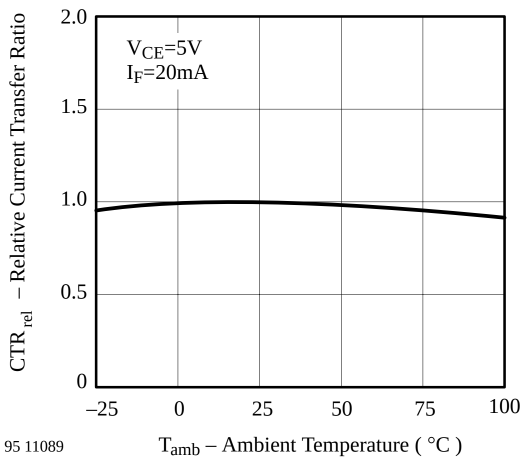


Figure 5. Relative Current Transfer Ratio vs. Ambient Temperature

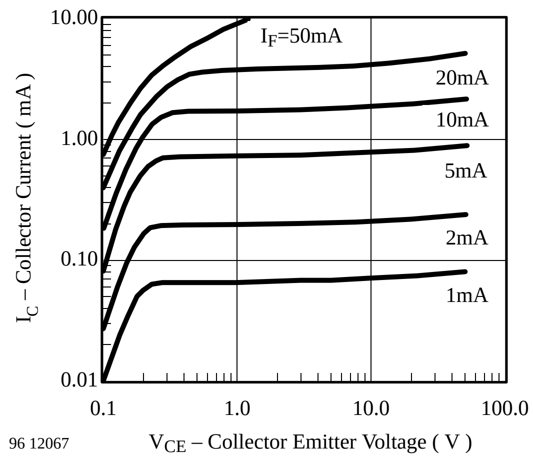


Figure 8. Collector Current vs. Collector Emitter Voltage

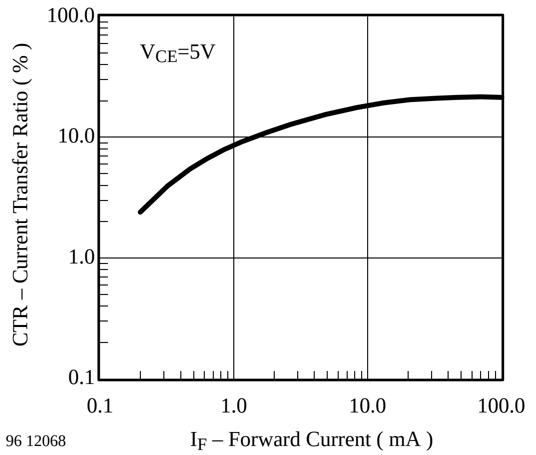


Figure 9. Current Transfer Ratio vs. Forward Current

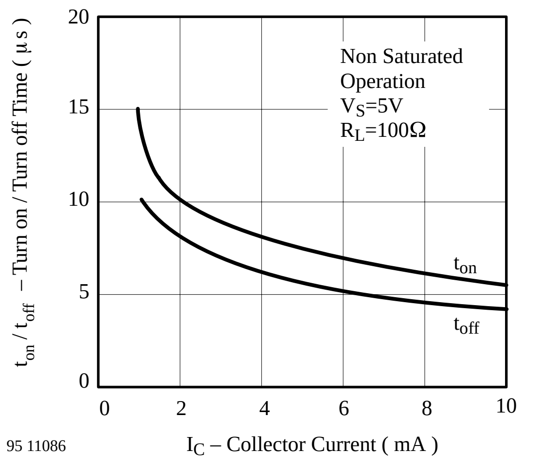


Figure 10. Turn on / off Time vs. Collector Current

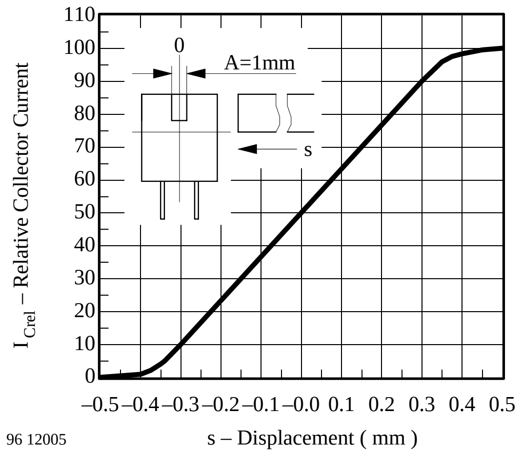


Figure 11. Relative Collector Current vs. Displacement

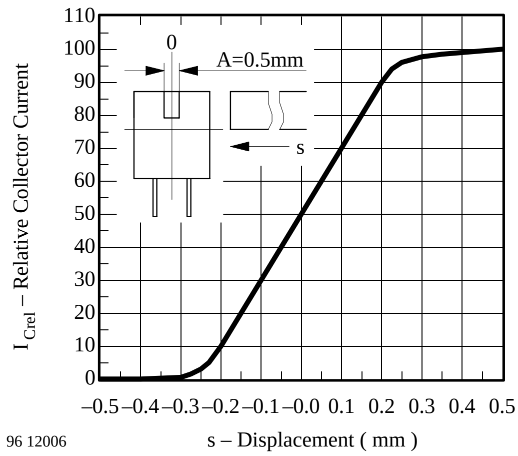


Figure 12. Relative Collector Current vs. Displacement

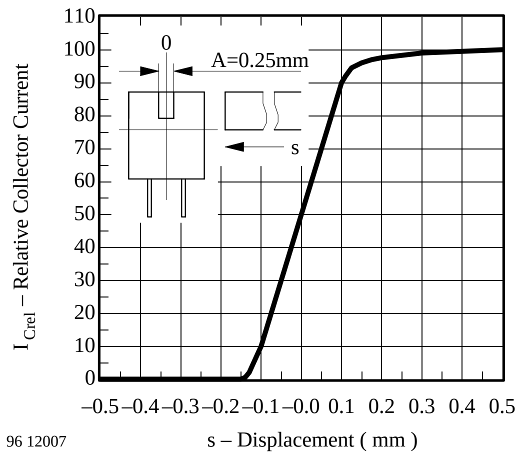
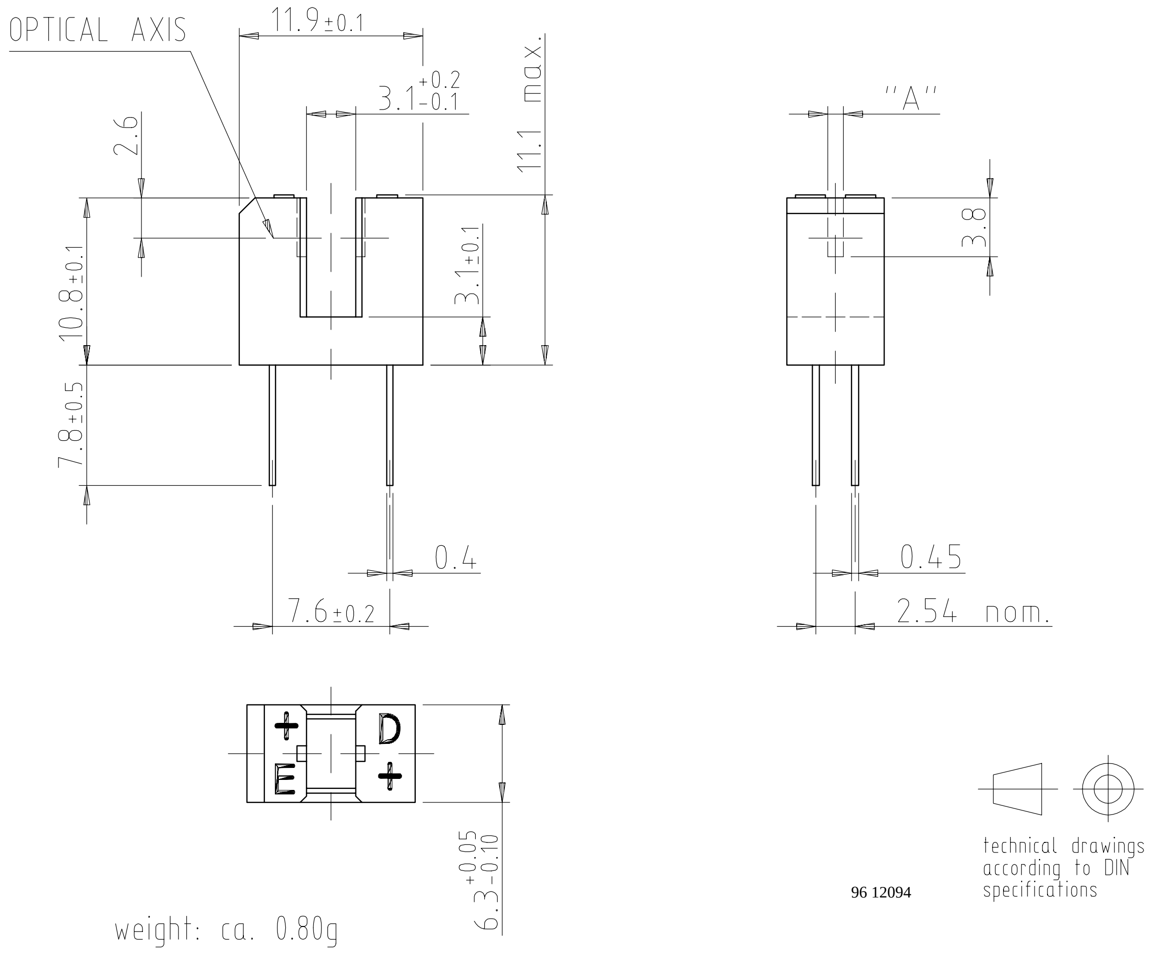
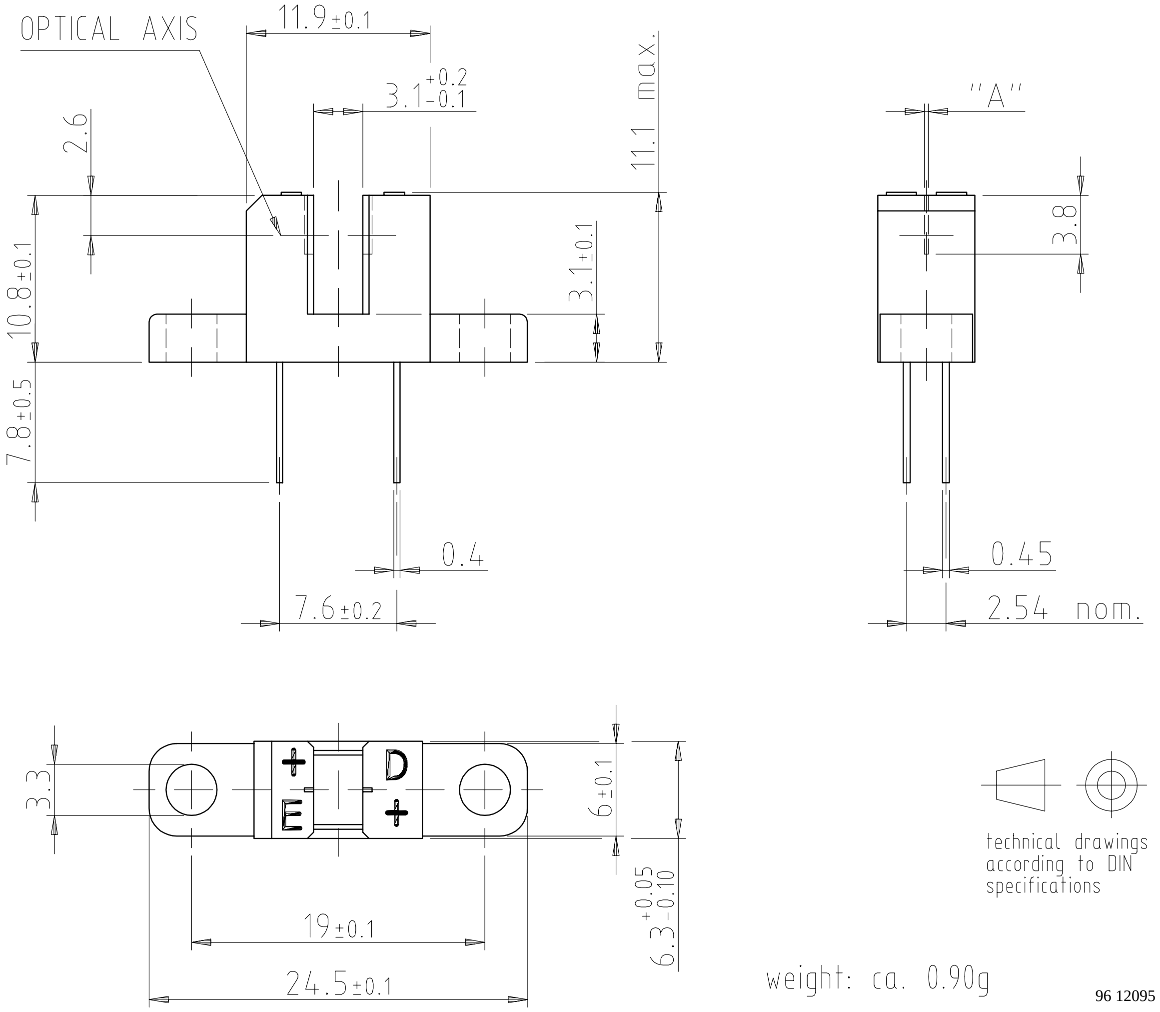


Figure 13. Relative Collector Current vs. Displacement

Dimensions of TCST1.0. in mm



Dimensions of TCST2.0. in mm



Ozone Depleting Substances Policy Statement

It is the policy of **Vishay Semiconductor GmbH** to

1. Meet all present and future national and international statutory requirements.

2. Regularly and continuously improve the performance of our products, processes, distribution and operating systems with respect to their impact on the health and safety of our employees and the public, as well as their impact on the environment.

It is particular concern to control or eliminate releases of those substances into the atmosphere which are known as ozone depleting substances (ODSs).

The Montreal Protocol (1987) and its London Amendments (1990) intend to severely restrict the use of ODSs and forbid their use within the next ten years. Various national and international initiatives are pressing for an earlier ban on these substances.

Vishay Semiconductor GmbH has been able to use its policy of continuous improvements to eliminate the use of ODSs listed in the following documents.

1. Annex A, B and list of transitional substances of the Montreal Protocol and the London Amendments respectively

2. Class I and II ozone depleting substances in the Clean Air Act Amendments of 1990 by the Environmental Protection Agency (EPA) in the USA

3. Council Decision 88/540/EEC and 91/690/EEC Annex A, B and C (transitional substances) respectively.

Vishay Semiconductor GmbH can certify that our semiconductors are not manufactured with ozone depleting substances and do not contain such substances.

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Telephone: 49 (0)7131 67 2831, Fax number: 49 (0)7131 67 2423

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