BRUSH DC MOTOR CONTROL MODULE

BDCMCM 3105; BDCMCM 3110

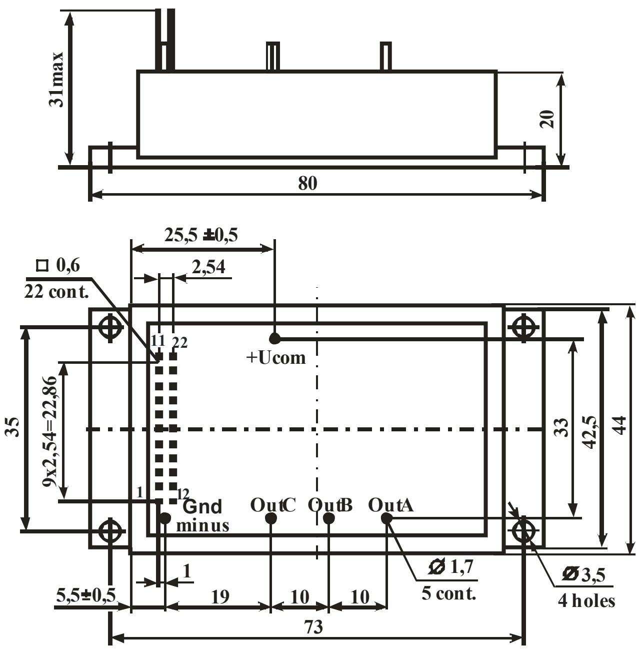
USER'S MANUAL

1 Function

1.1 Semiconductor module is intended for controlling, regulating and stabilizing of rotation velocity of brush DC motor with constant magnets and rotor position sensors.

2 Module technology and operation

2.1 The module is a hybrid assembly of air-tight structure in metal-plastic housing (Figure 1). There are vertical outputs on the top surface for bonding wire connection. The lower metal surface is heat-generating. To provide error-free performance you should install the module housing to a heat sink (a radiator or structural element).



1 – GND	12 – GND
2 – RC -	13 – RC+
3 - TC -	14 – TC-
4 – BREAK	15 – 60°/120°
5 – FWD/BCKW	16 – ENABLE
6 – In.TACH2	17 – OSC
7 – U CONTR.	18 – In.TACH1
8 – Rt/Ct	19 – U_{ref}
9 – ERROR	20 – F TACH
10 – SA	21 – SB
11 – Sup. RPS	22 – SC

Figure 1 – Overall drawing and output function

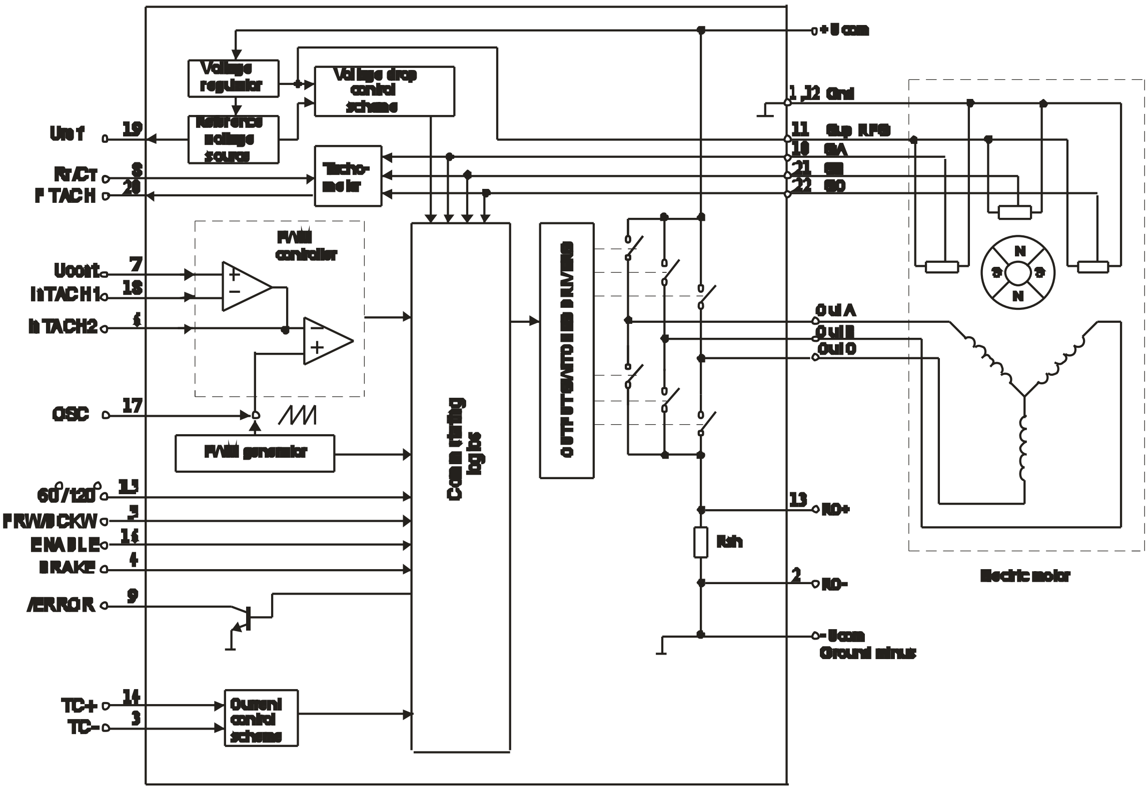


Figure 2 – Module structure circuit

2.2 The module is a high-integrated air-tight circuit that includes monolithic control circuit, built-in power supply, electronic tachometer circuit, power output switches of field transistor that are connected by three-phase inverter. The module allows you to control a three-phase DC motor with a rotor position sensor, providing: the regulation and stabilization of the motor speed, motor braking, measuring and limiting the level of the current consumed by the motor windings from an external source, outputting a signal "/ ERROR" in critical modes.

The module structure circuit is represented on Figure 2. The functional application of the module outputs is shown in Table 1.

Table 1 – Functional application of module output

Name	Application
$+U_{com}$	Motor operating voltage
$-U_{com}$ (gnd)	Ground minus
Sup RPS	Supply voltage of rotor position sensor (Hall sensors or optical ones)
SA, SB, SC	State control inputs of RPSs
Out A, Out B, Out C	Outputs to connect motor windings
U_{ref}	Source of reference voltage for organizing U_{contr} and forming charge current of timing capacitances C_T, C_G.
R_T/C_T	Connection of timing elements C_T и R_T determining duration pulses of rate stabilizer (tachometer)
FTACH	Tachometer signal output; its frequency is determined by the motor rotation speed, pulses duration – by value R_T, C_T and speed of motor
U_{contr}	Speed control signal, non-inverting input of amplifier PWM
In TACH1	Differential input of error signal inverting input of amplifier PWM
In TACH2	Differential input of error signal inverting input of comparator PWM
OSC	Connection of timing elements C_G, R_G determining frequency of generator PWM
$60^o/120^o$	Control by motor phasing mode
FWD/BCKW	Control by direction of motor rotor rotation
ENABLE	Enable to operate/motor stop
BRAKE	Dynamic motor braking
/ERROR	Output signal built by scheme OC having lower level active when becoming worse one of controlled parameter: incorrect sensors code combination; being of lower level (0) on in-

	put «ENABLE»; current consumption excess of motor higher than controlled limit; decreasing supply voltage lower than controlled level
TC+; TC-	Sensor inputs of current control scheme
RC+; RC-	Outputs (potential) of current-measuring shunt

2.3 The module contains the following functional units:

- voltage regulator to power the device components and units;
- reference voltage source with high temperature stability;
- control circuit of required levels of supplying voltages to ensure perfect device's operation;
- sawtooth waveform generator for the organization speed PWM-control;
- PWM controller which implements regulation (change and stabilization) speed of rotation of the motor rotor;
- electronic tachometer implementing feedback of control system. It converts RPS signals to an error signal that is proportional to the level of speed;
- circuit of control and limitation of current consumed by motor windings;
- circuit of current measurement consumed by motor windings;
- control drivers by output field effect transistors gates;
- three-phase inverter on complementary field effect transistors;
- switching logic that is controlled using four logic signals, that is consumed code combinations from RPS and generating signals of output switches driver control, outputting the signal "/ ERROR" in critical modes.

2.4 The variants of the module states at controlling the three-phase six-step AC motor are represented in Table 2.

Table 2 – Variants of module states at controlling the three-phase six-step AC motor

Inputs									Current sensor	Outputs				Note
60º/120º = 1			60º/120º = 0			FWD/ BCKW	ENABLE	BRAKE		Out A	Out B	Out C	/Error	
SA	SB	SC	SA	SB	SC									
1	0	0	1	0	0	1	1	0	0	1	-	0	1	
1	1	0	1	1	0	1	1	0	0	-	1	0	1	
1	1	1	0	1	0	1	1	0	0	0	1	-	1	FWD/BCKW=1
0	1	1	0	1	1	1	1	0	0	0	-	1	1	(p.1; p.2)
0	0	1	0	0	1	1	1	0	0	-	0	1	1	
0	0	0	1	0	1	1	1	0	0	1	0	-	1	
1	0	0	1	0	0	0	1	0	0	0	-	1	1	
1	1	0	1	1	0	0	1	0	0	-	0	1	1	
1	1	1	0	1	0	0	1	0	0	1	0	-	1	FWD/BCKW=0
0	1	1	0	1	1	0	1	0	0	1	-	0	1	(p.1; p.2)
0	0	1	0	0	1	0	1	0	0	-	1	0	1	
0	0	0	1	0	1	0	1	0	0	0	1	-	1	
1	0	1	1	1	1	X	X	0	X	-	-	-	0	p.3
0	1	0	0	0	0	X	X	0	X	-	-	-	0	
1	0	1	1	1	1	X	X	1	X	0	0	0	0	p.4
0	1	0	0	0	0	X	X	1	X	0	0	0	0	
V	V	V	V	V	V	X	1	1	X	0	0	0	1	p.5
V	V	V	V	V	V	X	0	1	X	0	0	0	0	p.6
V	V	V	V	V	V	X	0	0	X	-	-	-	0	p.7
V	V	V	V	V	V	X	1	0	1	-	-	-	0	p.8
p.1	The binary inputs «SA», «SB», «SC», «Fwd/Bckw», «ENABLE», «BRAKING», «60º/120º» have compatible TT levels. High level (1) on outputs «Out1», «Out2» means connection to «+U_{com}», low level (0) – connection to «- U_{com}» (ground minus)													
p.2	High level (1) on input «60º/120º» sets the phasing mode at 60 electrical degrees, low level (0) the phasing mode at 120 electrical degrees													

p.3	At incorrect combination on the inputs «SA», «SB», «SC», low level (0) on input «BRAKE»: outputs «A», «B», «C» are disconnected; the output «/ERROR» has the active low level (0) that built under the scheme with open collector
p.4	At incorrect combination on the inputs «SA», «SB», «SC», high level (1) on input «BRAKE»: outputs «A», «B», «C» are connected to «-U_{com}» (ground minus), the motor windings are connected to each other; using this a braking electromagnetic force is generated (dynamic brake); on the «/ERROR» - low level (0)
p.5	At correct combination on the inputs «SA», «SB», «SC» (V – any correct state on the sensor inputs corresponding to the phasing at 60º or 120º), hire level (1) on inputs «ENABLE» and «BRAKE» - then the outputs «A», «B», «C» are in the dynamic braking mode; on the output «/ERROR» - high level (1)
p.6	If on the input «ENABLE» low level (0), and on the input «BRAKE» high level (1) – then the outputs «A», «B», «C» are in the dynamic braking mode; on the output «/ERROR» - low level (0)
p.7	If on the inputs «ENABLE» и «BRAKE» the low level (0) – then the outputs «A», «B», «C» are disconnected; on the output «/ERROR» - low level (0)
p.8	At the current level (consumed by a motor from an external source) higher than determined limit - then the outputs «A», «B», «C» are disconnected; on the input «/ERROR» - low level (0). Signal of the current sensor is in-circuit, with operation threshold under level 100 mV on the current-measuring shunt. Logic zero (0) is generated at a level < 85 mV, logical level (1) – at a level > 115 mV

3 Basic specifications and characteristics

3.1 Basic electric characteristics are shown in Table 3.

3.2 Maximum permissible operating modes are shown in Table 4.

Table 3 – Basic electric characteristics

Parameter	Symbol	Unit	Value		Note
			BDCMCM 3105	BDCMCM 3110	
1 Maximum pulse supply voltage	$U_{sup.\ max}$	V	45		t_{pul}=5 ms
2 Maximum closed transistor voltage of control channel of motor winding	$U_{tr.max}$	V	100		
3 Control input voltage (outputs 4,5,15,16,10,21,22)	$U_{in.max}$	V	U_{ref}		
4 Input PWM-generator current (flow in or flow out current) (output 20)	I_{ocs}	mA	30		
5 Tachometer output current (flow in or flow out) (output 20)	I_{TACH}	mA	20		

Continuation of Table 3

Parameter	Symbol	Unit	Rate		Note
			BDCMCM 3105	**BDCMCM 3110**	
6 Input PWM amplifier range (flow in or flow out) (outputs 7,18)	$I_{in.ampl.max}$	mA	$-0.3 \div U_{ref}$		
7 PWM amplifier output current (flow in or flow out) (output 6)	$I_{out.ampl}$	mA	10		$-0.3 < U_{in.ampl} < U_{ref}$
8 Range of current control scheme input voltage (outputs 3, 14)	$U_{in.TC.max}$	V	$-0.3 \div 5.0$		
9 Voltage of output «ERROR» (output 9)	$U_{ce(/err)max}$	V	20		
10 Flow in current of output «ERROR» (output 9)	$I_{ce(/err)\ max}$	mA	20		
11 Output pulse current	$I_{pul.max}$	A	15		$t_{pul} < 30$ µs Q = 100
12 Maximum limitation current	$I_{lim.\ max}$	A	7.5	15	at di/dt=0.4A/µs
13 Isolation voltage	U_{isol}	V	500		DC,1 minute
14 Maximum junction temperature	$T_{j.max}$	°C	+150		
15 Thermal junction-housing resistance	$R_{th.\ j\text{-}h}$	°C/W	2		

Table 4 – Maximum permissible operating modes

Parameter	Symbol	Unit	Value				Note
			BDCMCM 3105		BDCMCM 3110		
			min	max	min	max	
1 Operation temperature range	T_{oper}	°C	-40	+85	-40	+85	
2 Storage temperature	T_{stor}	°C	-60	+100	-60	+100	
Input and reference voltage parameters							
1 Supply voltage	U_{sup}	V	15	29.7	15	29.7	
2 Module current consumption	I_{cons}	mA	40	60	40	60	U_{com}=27V±10%
3 Supply voltage of RPS	$U_{sup\ RPS}$	V	21.9	25.1	21.9	25.1	$I_{sup\ RPS}$=30 mA
4 Reference voltage (output 19)	U_{ref}	V	5.82	6.57	5.82	6.57	T= (-40÷85) °C I_{ref} = 1 mA
5 Reference voltage change	ΔU_{ref}	mV	30				I_{ref} = (1÷20) mA
6 Output current of reference voltage source	I_{ref}	mA	40	70	40	70	
7 Threshold off voltage of reference voltage source	$U_{ref.off}$	V	4	5	4	5	
8 Module shutdown voltage at supply voltage decrease	U_{off}	V	9.5	11.3	9.5	11.3	
PWM-controller parameter							
1 Input voltage of amplifier bias	U_{bias}	mV	0.4	10	0.4	10	
2 Difference of input amplifier currents	I_{isol}	nA	80	500	80	500	
3 Input bias current	I_{bias}	nA	-46	-1000	-46	-1000	
4 Input common-mode voltage range	U_{ICR}	V	$0 \div U_{ref}$				
5 Coefficient of amplification without FB	A_{VOL}	dB	70	80	70	80	Uin=3 V, R_L=15 kΩ
6 Reduction coefficient of common-mode signal	CMMR	dB	55		55		

Continuation of Table 4

Parameter	Symbol	Unit	Rate				Note
			BDCMCM 1105		BDCMCM 1110		
			min	max	min	max	
7 Output voltage of comparator switching: High level Low level	 $U_{in\ H}$ $U_{in\ L}$	V	 4.6	 1.0	 4.6	 1.0	R_L=15kΩ, connection to GND, R_L=15 kΩ connection to U_{ref}
PWM generator parameter (output 17)							
1 Generator frequency	F_{ocs}	kHz	22	28	22	28	
2 Maximum peak saw-tooth voltage	$U_{ocs.}$(H)	V	4.6		4.6		
3 Minimum peak saw-tooth voltage	$U_{ocs.}$(L)	V		1.0		1.0	
Electronic tachometer parameters							
1 Charge current Cт (flowing in) (output 8)	I_{charge}	mA	20	60	20	60	
2 Output voltage (output 20): high level low level	 U_{VH} U_{VL}	 V V	 3.6 0	 4.2 0.5	 3.6 0	 4.2 0.5	 I_{TACH}=5 mA I_{TACH}= -10 mA
3 Non-stability of output signal pulse duration	$t_{n\text{-}stab}$	µs	205	245	205	245	T= (-40÷85) °C
Control signals parameters							
1 Input threshold voltage (outputs 4, 5, 15, 16, 10, 21, 22) High level Low level	 $U_{in\ h}$ $U_{in\ l}$	 V V	 3.0	 0.8	 3.0	 0.8	
2 Input current (outputs 10, 21, 22) High level Low level	 $I_{in\ h}$ $I_{in\ l}$	 µA µA	 -190 -800	 -100 -500	 -190 -800	 -100 -500	 $U_{in\ H}$ = 5 V $U_{in\ L}$= 0 V
3 Input current (outputs 4, 5, 15) High level Low level	 $I_{in\ h}$ $I_{in\ l}$	 µA µA	 -75 -300	 -10 -150	 -75 -300	 -10 -150	 $U_{in\ H}$ = 5 V; $U_{in\ L}$= 0 V
Parameter of control circuit and current limitation							
1 Threshold voltage	U_{thresh}	mV	85	115	85	115	
2 Input bias current	I_{bias}	µA		-5.0		-5.0	
3 Input common-mode voltage range	U_{ICR}	V	3				
4 Voltage of current-measuring resistor outputs (outputs 2 , 13)	U_{RC}	mV	95	105	95	105	I_m = I_{lim}
5 Limitation current	I_{lim}	A	4.5	5.5	9.0	11	
Output signals parameters							
1 On-state resistance of power transistor	$R_{ds.on}$	Ω		0.1		0.1	I_m= I_{lim}
2 Closed transistor leakage current of three-phase inverter	$I_{l.tr}$	µA		100		100	U_{ds}=100 V U_{gs}=0 V
3 Saturation voltage on output «ERROR» (output 9)	$U_{ce.r}$	mV		500		500	I_c=16 mA
4 Leakage current of output «ERROR» (output 9)	$I_{c.l}$	µA		100		100	U_{ce} = 20 V
5 Switching duration of top switches Rise time Fall time	 $t_{r.h}$ $t_{f.l}$	 µs µs	 2.5 5	 5 10	 2.5 5	 5 10	

6 Switching duration of low switches Rise time Fall time	 $t_{r.h}$ $t_{f.l}$	 µs µs	 1 1	 1.5 1.5	 1 1	 1.5 1.5	
7 Switching delay when current level exceeding	$t_{off.c}$	µs	10	20	10	20	

4 Application recommendations

4.1 The inputs «SA», «SB», «SC» allow the possibility of direct connection the rotor position sensors (Hall sensors; optocoupler sensors) having the outputs with open collector, either they output the signals of TTL.

4.2 The module allows using different algorithms to phase the motor rotor. In dependence on the sensors' positions there are four algorithms for the motor positioning (60°, 120°, 240°, 300°). Sensors state in dependence on the rotor position is changed in accordance with the diagram shown on Figure 3.

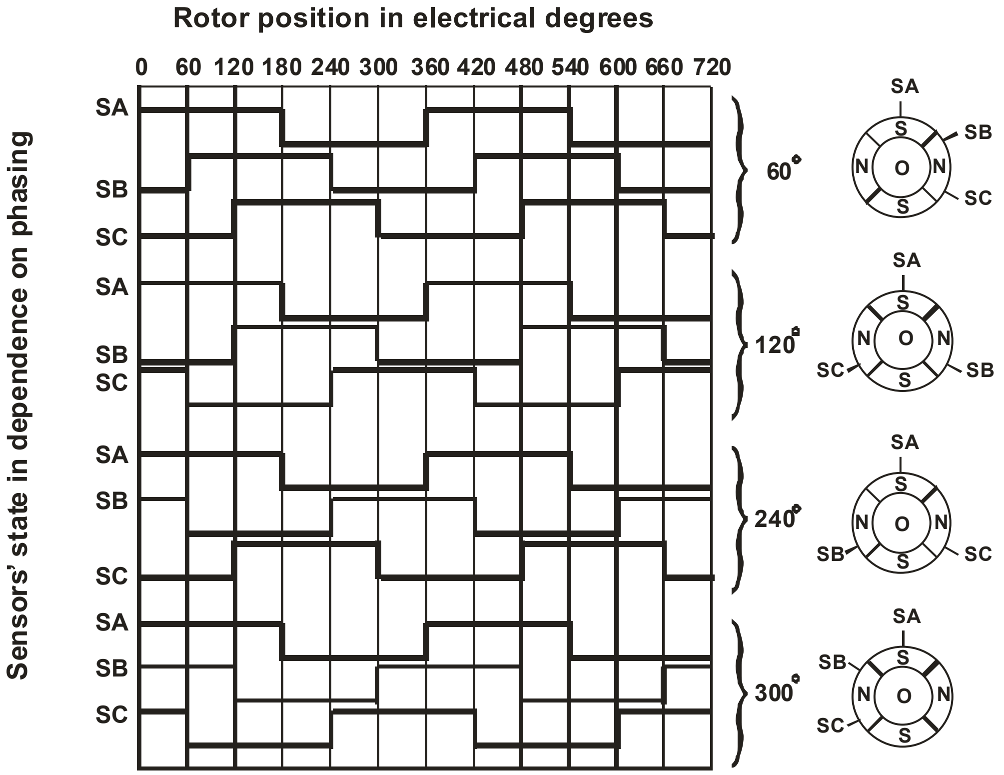


Figure 3 – State diagrams of positions sensors

Algorithms 60 ° and 300 ° or 120 ° and 240 ° are symmetrical but the rotor rotation direction for them is opposite. For example, when applying the RPS signals to the inputs "SA", "SB", "SC" with the phasing algorithm 60 ° or 120 °, the module outputs current signals of control motor for forward rotation, and when RPS signals are coming with phasing algorithm 240 ° or 300 ° - for reverse rotation.

Change the direction of the motor rotation allows the low-level signal (0) applied to the input of "FWD / BCKW", thus, there is an inverting of current signals motor control in accordance with Table 2.

Thus, the module using the command "60 ° / 120 °» and "FWD / BCKW", allows you to implement any of the suggested phasing algorithm.

These algorithms correspond to the six combinations of eight possible ones of three-bit code. Two code combinations are prohibited. When inputting to the inputs "SA", "SB", "SC" incorrect, for certain algorithm of phasing, code combination the module disables the output transistors and outputs the signal "/ ERROR."

4.3 Signal "ENABLE" may be used when switching the direction of motor rotation and to operate the dynamic braking mode.

4.3.1 If the rotation direction is changed it is necessary to install low level (0) signal on the «ENABLE» input, therewith the module power transistors will be closed. After that you should change rotation direction signal «FWD/BCKW».

Timing diagram of recommended signal sequence to «ENABLE» and «FWD/BACK» inputs are shown at Figure 4.

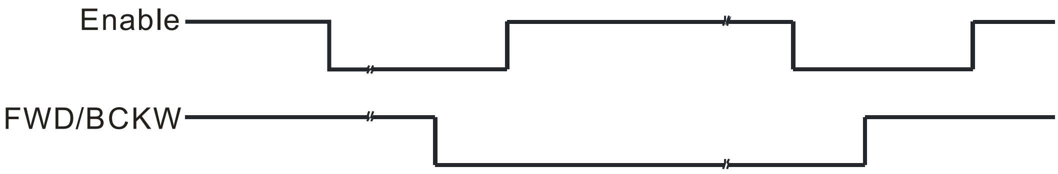


Figure 4

4.3.2. In order to control the dynamic braking mode you should install low level signal to «ENABLE» input therewith the module power transistor will be closed. After that, to open "lower" transistor of the three-phase inverter, to output on the input "BRAKE" pulses with the desired duty cycle. Changing the duty cycle "BRAKE" may change the stiffness of the dynamic braking mode.

Timing diagram of control signal of PWM-regulation by dynamic braking is shown at Figure 5.

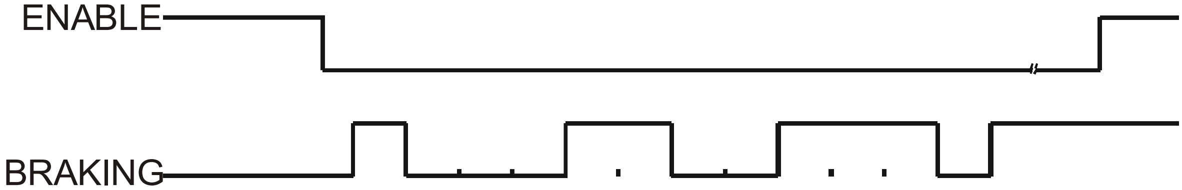


Figure 5

4.4 The input "BRAKE" has priority over other control inputs. High level (1) signal delivery provides the transition to the dynamic braking mode. Thus, "top" transistors of the three-phase inverter connected to «+U_{com}» will be closed. "Bottom" transistors of the three-phase inverter will be open, connecting the all motor winding to «-U_{com}» (ground minus). Thus, the winding is closed between each other; that creates braking electromagnetic force.

4.5 PWM-generator is adjusted by means of external elements Rg and Cg, connection circuit is shown at Figure 6a.

Capacitor Cg is charged from the reference voltage source U_{ref} through a resistor Rg and discharged through the internal transistor. To reduce the acoustic level noise and to provide an effective level of motor control current signal, it is necessary to set the PWM-generator frequency in the range 20 ... 30 kHz.

PWM-generator frequency dependence on the values Cg and Rg is shown on the nomogram of Figure 6b.

For example, the optimal frequency of the generator 25 kHz is installed when you select Cg = 0.01 µF, Rg = 4.7 kΩ.

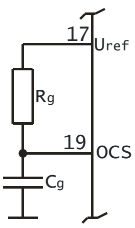


Figure 6a

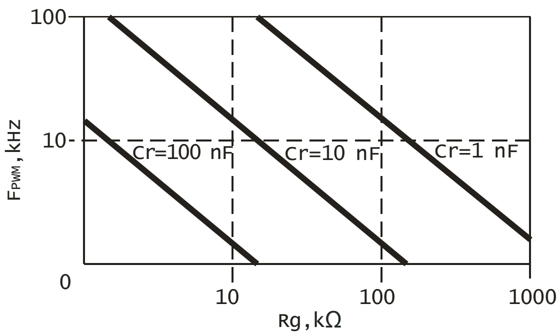


Figure 6b

4.6 When rotating the motor shaft the tachometer converts electronic signals "RPS" to the pulse sequence of an output signal "FTACH." The period of the generated pulses corresponds to rotation motor speed, the pulse duration t_{pul} specified by the elements' values St and Rt.

Connection elements' diagram Ct and Rt is shown in Figure 7a. In this case the maximum speed of the motor (in the case of application of internal feedback) may limit by the pulse duration Rt/Ct - circuit, i.e., increasing the value of t_{pul} reduces the motor speed $t_{pul} = 10 / (N \cdot A)$,

where N – the motor speed, rpm;

A – a number of cycles of repetition of code combination per one rotation of motor shaft.

To choose the elements RT, CT it is necessary to use the nomogram shown on Figure 7b.

For example, if the motor speed 5000 rpm, and per one rotation of the shaft happens two changing cycles of code sequences on the outputs «RPS», then t_{pul} =1 ms. For the chosen elements RT =43 kΩ, CT = 22 nF, the pulses duration t_{pul} = 950 µs.

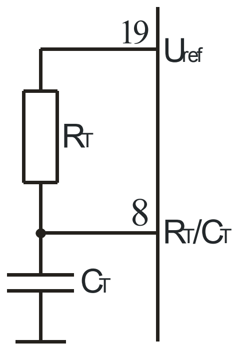


Figure 7a

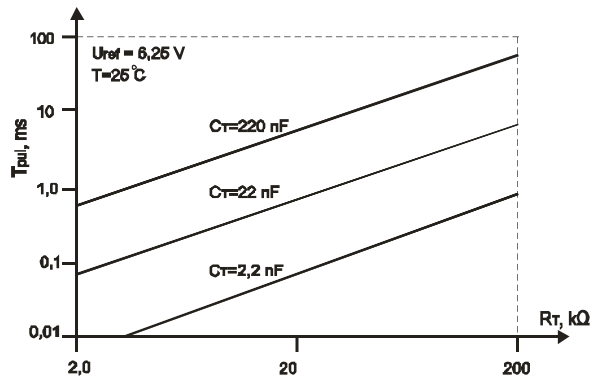


Figure 7b

4.7. The module controls the current value consumed by the motor from the external source at the internal current-measuring resistor (outputs «Rc +», «Rc-»). The signal from these outputs can be directly connected to the current limiting circuit (inputs "TC +", "TC-") or use in the circuit of the external current limiting circuit. The possible connection diagram is shown in Figure 8.

From the additional elements R1, R2, C1 consist LPF prevents ingress of impulse noise on the input of the current limiting circuit comparator.

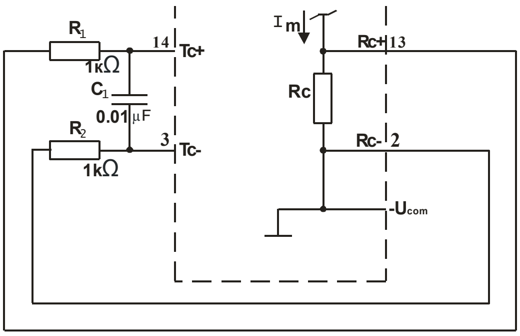


Figure 8

4.8 To control motor rotation speed the multiple single-polar two-side PWM method is used in the module; it changes average voltage value, applied to collector motor winding during the commutating cycle.

Thereby top transistor of the three-phase inverter (that connects stator winding to «+U_{com}») is conducting, regulation is performed by low transistor switching (that connects stator winding to «-U_{com}»). Timing PWM-regulation diagram of motor speed is shown at Figure 8. As soon as the capacitor Cg of WM-generator is discharged the power transistors of the three-phase inverter will be open thereby supplying current to the stator's winding. When the level of accumulative saw-tooth voltage of Cg capacitor is more than the signal level of PWM-amplifier output (In TACH2), then the low transistor of the three-phase inverter is closed thereby disconnecting the current in the supply circuit of the motor stator's winding. If signal level of PWM-amplifier output (In TACH2) exceeds the peak value of saw-tooth voltage of PWM-generator, then PWM-regulation ends, the motor is rotated at maximum speed. If current level that is consumed by the motor winding is more than the limit value (on outputs «Tc+», «Tc-» signal U > 100 mV) then transistors of the three-phase inverter will be totally disconnected, on the output «ERROR» - low level (0).

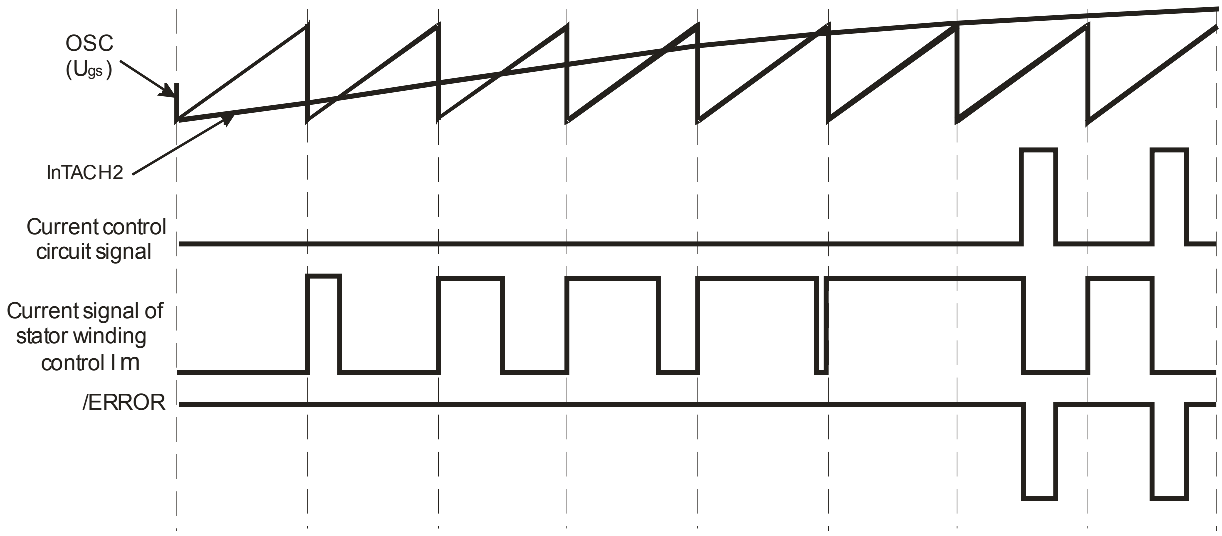


Figure 9 – Diagram of motor speed PWM-regulation

4.9 The module can be used in the modes of open FB loop (when stabilization and speed control problem is resolved by other devices) and of closed FB loop (when speed control in different functions is carried out by module facilities).

4.10 Speed level control is performed by means of potential signal that is delivered to «U_{cont}» input, the possible connection circuit shown at Figure 10.

4.11 If the module is used in the mode of open FB loop then the PWM-amplifier will operate in the mode voltage repeater. The connection example is shown at Figure 11.

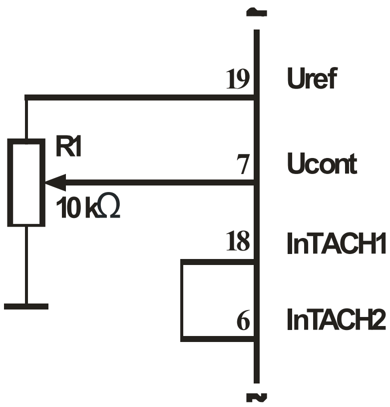


Figure 10

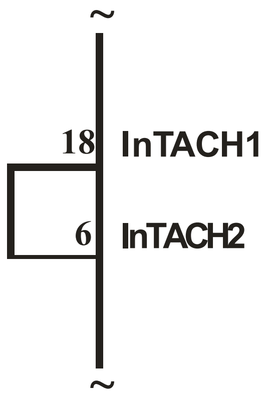
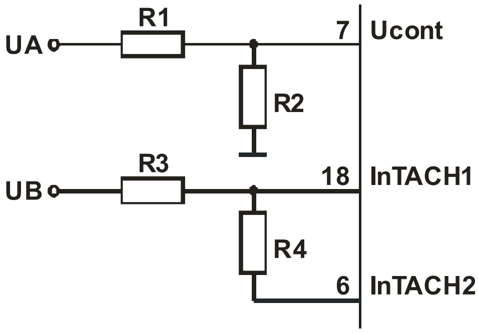


Figure 11

The variant of speed control mode application by two differential inputs is shown at Figure 12.

The dependence of duration of current control signal of motor winding versus PWM input voltage is shown at Figure 13.



$$U_{InTACH2} = UA \times (\frac{R3+R4}{R1+R2}) \times \frac{R2}{R3} - (\frac{R4}{R3} \times UB)$$

Figure 12

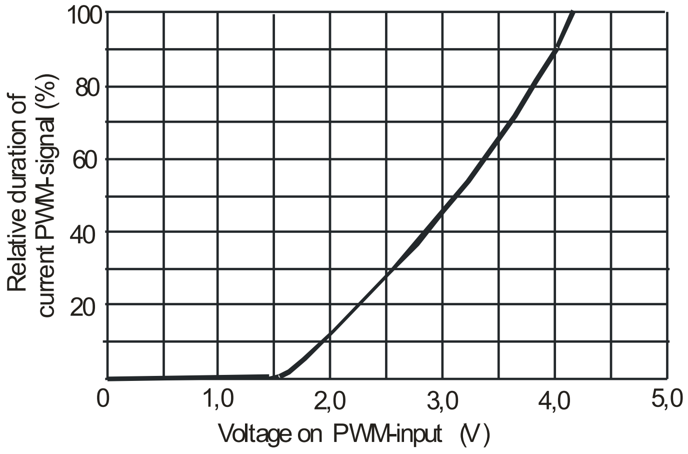


Figure 13

4.12 The module may be used in acceleration/deceleration control mode. The virtual turn-on circuit is shown at Figure 14. The resistor and the condenser R1 and C1 determine the constant of acceleration time, and the R2 and C1 – deceleration time. The resistance values of R1 and R2 should be many times less than resistance value R3.

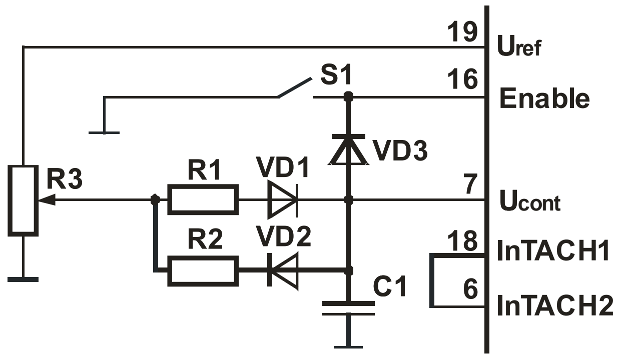


Figure 14

4.13 In the case of use the module in the FB closed loop mode (for speed stabilization you can use the possibilities of the module) is necessary to send a FB signal on the inverting input of the PWM-amplifier; the signal is proportional to the speed level.

The principle of forming a feedback signal is shown on Figure 15. Simply enough such signal is generated by integrating the signal of the electronic tachometer «FTAX». Connection diagram of the integrator's elements of proportional speed control (stabilization) is shown on Figure 16. Provided that the nominal elements are correctly selected the integrator / amplifier PWM will produce a signal that free from pulsation even if the motor speed is low. However, in such the designed decision at the lowest speed is slightly gone bad the reaction system. It is necessary to use the components' values according with motors' electromechanical characteristics. For the elements integrator time constant t=100 ms, it allows getting the good dynamic reaction and stability for the most uses.

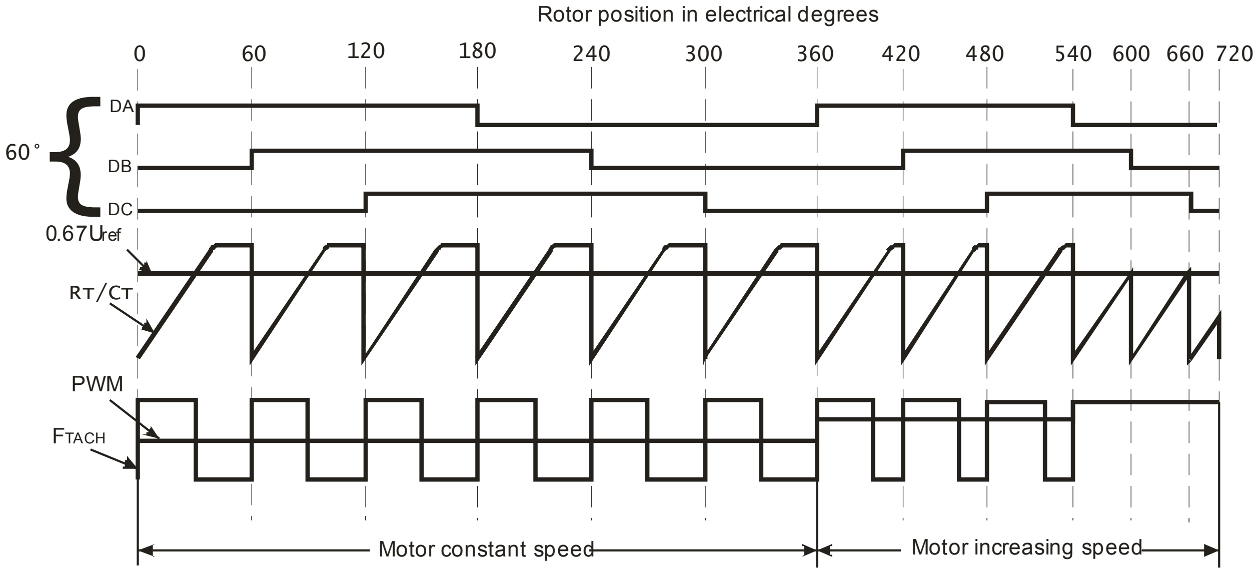


Figure 15 – Proportional speed regulation FB signal forming

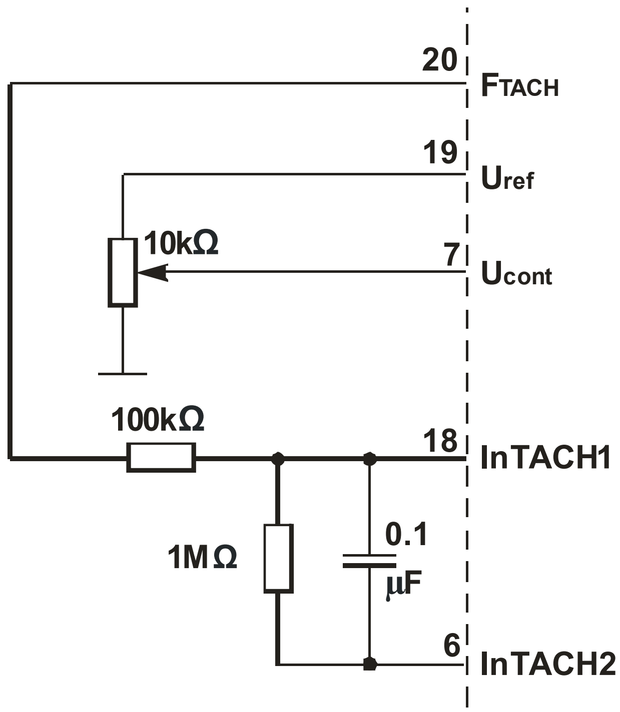


Figure 16

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