BRUSHLESS DC CONTROL MODULE
BLDCCM 3105; BLDCCM 3110

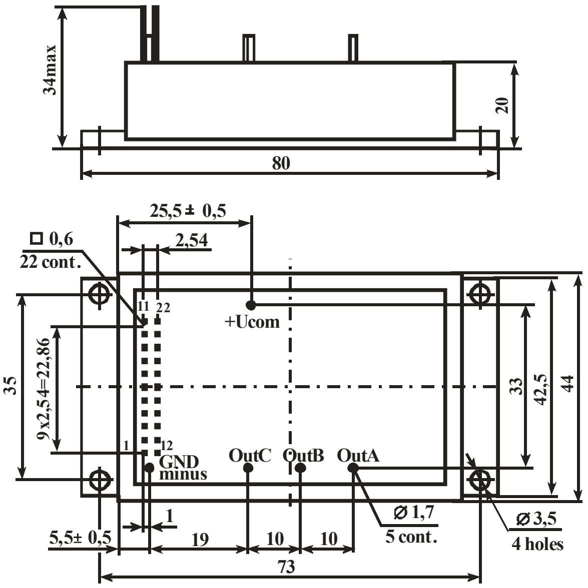
TICKET

1 Function

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

2 Module technology and operation

2.1 The module is 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 (radiator or structural component).



1 – GND
2 - RC -
3 – TC -
4 - Braking
5 - Fwd/Back
6 - In.TAX2
7 - U cont
8 – R_t/C_t
9 - ERROR
10 - DA
11 – S.RPS
12 – Gnd
13 – RC+
14 - TC+
15 - 60°/120°
16 - ENABLE
17 – OCS
18 –In.TAX1
19 – U_{ref}
20 – F TAX
21 – DB
22 – DC

Figure 1 – Overall drawing and output function

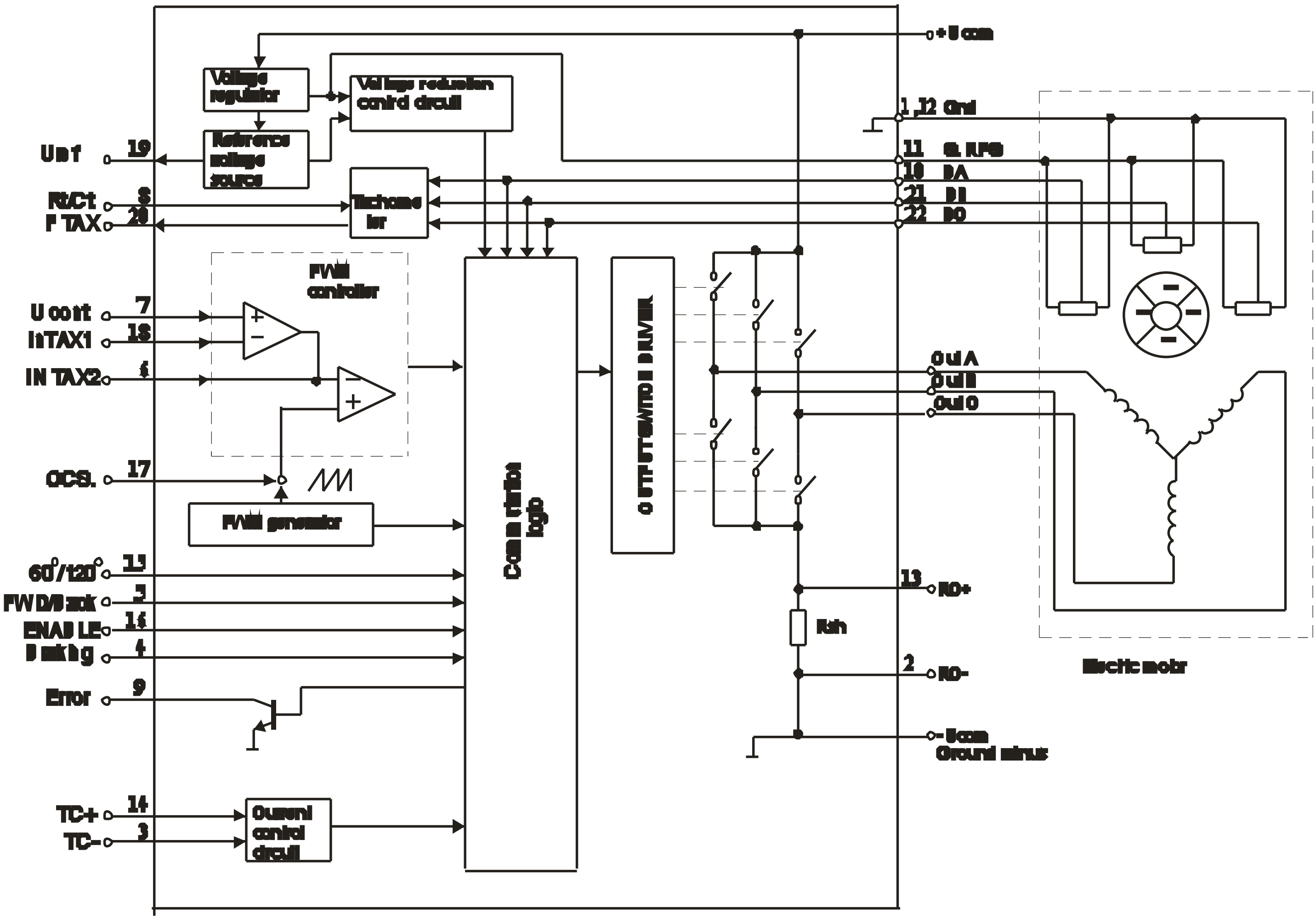


Figure 2 – Structure circuit

2.2 The module is a high integrated hybrid circuit that includes a monolithic circuit, an electric tachometer circuit, a built-in power supply, power output switches of field transistor that are connected by three-phase inverter circuit. The module enables to control three-phase DC motor with RPS providing: regulation and stabilization motor rotation velocity, braking, change and limitation of current level consumed by motor windings from external source, «ERROR» signal delivery in critical modes.

Structure module circuit is shown at Figure 2. Output functions are represented in Table 1.

Table 1 – Output functions

Symbol	Function
+U com	Operating voltage
- U com (Gnd)	Ground minus
S RPS	Supply voltage of rotor position sensor (Hall sensor or optical sensors)
DA, DB, DC	Control inputs of RPS state
Out A, Out B, Out C	Outputs of motor winding connection
U_{ref}	Reference voltage source for U_{cont} foundation and charge current generation of timing capacitances Ct, Cg.
Rt/Ct	Connection of timing elements C_t and R_t that determine pulse time of velocity stabilization (tachometer)
FTAX	Tachometer signal output, its frequency is determined by motor rotation velocity, pulse time – by Rt, Ct value and by motor velocity
U cont	Velocity control signal, non-inverting input of PWM amplifier
In TAX1	Differential input of error signal, inverting input of PWM amplifier
In TAX2	Differential input of error signal, inverting input of PWM comparator
OCS	Connection of timing elements Cg, Rg that determines PWM generator frequency
$60^o/120^o$	Control of phasing mode
Fwd/Back	Control of rotor rotation direction
ENABLE	Operation enable/motor shutdown
Braking	Dynamic braking
ERROR	Output signal built by OC circuit, it has active low level when one of the controlled parameters is impaired: faulty code sensor combination; low level (0) on input «Enable»; current consumption increase by more than controlled limit; supply voltage decrease by lower than the controlled level
TC+; TC-	Sensor input of current control circuit
RC+; RC-	Outputs (potential) of current-measuring shunt

2.3 Module contains the following functional blocks:

- Voltage regulator for elements and device units supply;
- Reference voltage source with high temperature stability;
- Control circuit of voltage levels for non-failure operation;
- PWM-controller realize regulation (change and stabilization) of rotor rotation velocity;
- Saw-tooth signal generator for velocity PWM-regulation;
- Electric tachometer that realizes FB of regulation system. It converts RPS signals into error signal that is proportional to velocity level;
- Circuit of current control/limitation consumed by motor winding;
- Gate control driver of output field transistors;
- Three-phase inverter of complementary field transistor;
- Commutation logic that is controlled by means of four logic signal, it receives the code combination from RPS and generates driver control signals of output switches, it gives “Error” signal in critical conditions.

2.4 Module state variants when driving of three-phase six-step brushless motor is shown in Table 2.

Table 2 – Module state variants when driving of three-phase six-step brushless motor

Inputs										Outputs				
60°/120° = 1			60°/120° = 0											
DA	DB	DC	DA	DB	DC	Fwd/Back	Enable	Brake	Current sensor	Out A	Out B	Out C	/ERROR	Note
1	0	0	1	0	0	1	1	0	0	1	-	0	1	Fwd/Back=1 (p.1; p.2)
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	
0	1	1	0	1	1	1	1	0	0	0	-	1	1	
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	Fwd/Back =0 (p.1; p.2)
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	
0	1	1	0	1	1	0	1	0	0	1	-	0	1	
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	Binary inputs «DA», «DB», «DC», «FWD/BACK», «ENABLE», «BRAKING», «60º/120º» have TTL-compatible levels. High level (1) at outputs «A», «B», «C» means the connection to «+U_{com}», low level (0) – connection to «– U_{com}» (GND minus).
p.2	High level (1) at output «60º/120º» installs phasing mode of 60 electric degrees, low level (0) – phasing regime of 120 electric degrees
p.3	When faulty combination at «DA», «DB», «DC», low level (0) at «BRAKING» output: outputs «A», «B», «C» are disconnected; output «ERROR» built by open collector circuit has active low level (0)
p.4	When faulty combination at «DA», «DB», «DC» inputs, high level (1) at «BRAKING» input: outputs «A», «B», «C» are connected to «-U_{com}» (ground minus), motor windings are closed between, therewith braking electromagnetic force (dynamic brake) is created; at «/ERROR» input – low level (0)
p.5	When faulty combination at «DA», «DB», «DC» inputs (V – any right state of sensor inputs corresponding to phasing of 60º or 120º), high level (1) at «ENABLE» and «BRAKING» inputs - «A», «B», «C» outputs are in the mode of dynamic braking; at « ERROR» output – high level (1)
p.6	In case of low level (0) at «ENABLE» input and high level (1) at «BRAKING» input - «A», «B», «C» outputs are in the mode of dynamic braking; at « ERROR» output - low level (0)
p.7	In case of low level at «ENABLE» and «BRAKING» inputs - «A», «B», «C» outputs are disconnected; at « /ERROR» output – low level (0)
p.8	If current level (consumed by the motor from external source) is higher than the prescribed limit - «A», «B», «C» outputs are disconnected; at « ERROR» output – low level (0). Current sensor signal is in-circuit, with level operation threshold 100 mV at current-measuring shunt. Logic-0 (0) is generated when level is < 85 mV, logic-1 (1) – when level is > 115 mV.

3 Basic specifications and characteristics

3.1 Basic electric characteristics are shown in Table 3.
3.2 Maximum permissible service modes are shown in Table 4.

Table 3 – Basic electric characteristics

Parameter	Symbol	Unit	Rate		Note
			BLDCCM 3105	BLDCM 3110	
1 Max pulse supply voltage	$U_{s.\ max}$	V	45		t_p = 5 ms
2 Max closed transistor voltage of control channel of motor winding	$U_{tr.max}$	V	100		
3 Voltage of control inputs (outputs 4,5,15,16,10,21,22)	$U_{in.max}$	V	U_{ref}		
4 Input current of PWM generator (drain or source current) (output 17)	I_{ocs}	mA	30		
5 Tachometer output current (drain or source current) (output 20)	I_{tach}	mA	20		
6 Input voltage range of PWM amplifier (outputs 7,18)	$U_{in.ampl.max}$	V	-0.3÷U_{ref}		
7 Output current of PWM amplifier (drain or source) (output 6)	$I_{out.ampl}$	mA	10		$-0.3<U_{in.ampl}<U_{ref}$
8 Input voltage range, range of current control circuit (outputs 3, 14)	$U_{in.\text{тс}.max}$	V	-0.3÷5.0		
9 Voltage of «ERROR» output (output 9)	$U_{ce\ (/er)max}$	V	20		
10 Drain current of «ERROR» output (output 9)	$I_{ce\ (/er)\ max}$	mA	20		
11 Output pulse current	$I_{\text{р мах}}$	A	15		tp < 30 μs Q = 100
12 Max limitation current	$I_{lim.\ max}$	A	7.5	15.0	At di/dt=0.4A/ μs
13 Isolation voltage	U_{isol}	V	500		DC, 1 minute
14 Max junction temperature of transistors	$T_{j.max}$	°C	+150		
15 Thermal junction-housing resistance	$R_{th.\ j\text{-}h}$	°C/W	2		

Table 4 – Maximum permissible service modes

Parameter	Symbol	Unit	Rate				Note
			BLDCCM 3105		BLDCM 3110		
			min	max	min	max	
1 Operating temperature range	T_{oper}	°C	-40	+85	-40	+85	
2 Storage temperature	T_{stor}	°C	-60	+100	-60	+100	
Input and output voltage characteristics							
1 Supply voltage	U_S	V	15	29.7	15	29.7	
2 Current consumption	I_{cons}	mA	40	60	40	60	U_{com}=27 B±10%
3 Supply voltage of RPS	$U_{s\ RPS}$	V	21.9	25.1	21.9	25.1	$I_{s\ rps}$=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

Continuance of Table 4

Parameter	Symbol	Unit	Rate BLDCCM 3105 min	Rate BLDCCM 3105 max	Rate BLDCM 3110 min	Rate BLDCM 3110 max	Note
6 Output source current of reference voltage	I_{ref}	mA	40	70	40	70	
7 Threshold turn-off voltage of reference voltage source	$U_{ref.off}$	V	4	5	4	5	
8 Turn-off voltage when reduction of line voltage	U_{off}	V	9.5	11.3	9.5	11.3	
PWM- controller characteristics							
1 Input bias voltage of amplifier	U_{bi}	mV	0.4	10	0.4	10	
2 Difference of input amplifier currents	I_{io}	nA	80	500	80	500	
3 Input bias current	I_{bi}	nA	-46	-1000	-46	-1000	
4 Input common-mode voltage range	U_{ICR}	V	$0 \div U_{ref}$				
5 Amplification factor without FB	A_{VOL}	dB	70	80	70	80	U_{in}=3 V, R_L=15 kΩ
6 Reduction factor of common-mode signal	CMMR	dB	55		55		
7 Output voltage of comparator switching: High level Low level	 U_h U_l	V	 1.0	 4.6	 1.0	 4.6	R_L=15 kΩ, connection to GND, R_L=15 kΩ connection to U_{ref}
PWM generator characteristics (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	
Characteristics of tachometer							
1 Charge current C_d (drain) (output 8)	I_{disch}	mA	20	60	20	60	
2 Output voltage (output 20): High level Low level	Uh Ul	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 Instability of pulse duration of output signal	t_{instab}	μs	205	245	205	245	T= (-40÷85) °C
Control signal characteristics							
1 Input threshold voltage (output 4, 5, 15, 16, 10, 21, 22): High level Low level	 U_h U_l	V	 3.0 	 0.8	 3.0 	 0.8	
2 Input current (outputs 10, 21, 22): High level Low level	 I_h I_l	 μA μA	 -190 -800	 -100 -500	 -190 -800	 -100 -500	 U_h=5 V U_l=0 V
3 Input current (outputs 4, 5, 15): High level Low level	 I_h I_l	 μA μA	 -75 -300	 -10 -150	 -75 -300	 -10 -150	 U_h=5 V U_l=0 V
4 Input current (output 16) High and low level	I_{in}	μA	-60	-10	-60	-10	U_h=5 V; U_l=0 V

Continuance of Table 4

Parameter	Symbol	Unit	Rate				Note
			BLDCCM 3105		BLDCM 3110		
			min	max	min	max	
Characteristics of control circuit and current limitation circuit							
1 Threshold voltage	U_{thr}	mV	85	115	85	115	
2 Input bias current	I_{bi}	μA		-5.0		-5.0	
3 Rate of input common-mode voltage	U_{ICR}	V	3				
4 Voltage of current-measuring resistor output (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	11.0	
Characteristics of output signals							
1 On-state resistance of power transistor	R on	Ω		0.1		0.1	$I_m = I_{lim}$
2 Leakage current of closed transistor of three-phase inverter	$I_{l.tr}$	μA		100		100	U_{ds}=100 V U_{gs}=0 V
3 Saturation voltage of output «ERROR» (output 9)	$U_{ce.sat}$	mV		500		500	I=16 mA
4 Leakage current of output «ERROR» (output 9)	I_l	μA		100		100	U_{ce} = 20 V
5 Switching time of top switches of Rise time Fall time	 $T_{r.in}$ $T_{f.in}$	 μs μs	 2.5 5	 5 10	 2.5 5	 5 10	
6 Switching time of low switches of Rise time Fall time	 $T_{r.l}$ $T_{f.t}$	 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 Outputs «DA», «DB», «DC» admit of the possibility of the immediate connection of rotor position sensors (Hall sensor, opto sensor) that have on collector outputs, or generating TTL-level signal.

4.2 The module allows using diverse phasing algorithms of motor rotor. Subject to sensor position there are four algorithms of motor positioning (60°, 120°, 240° and 300°). Sensors' state versus rotor position is changed in accordance with the diagram shown at Figure 3.

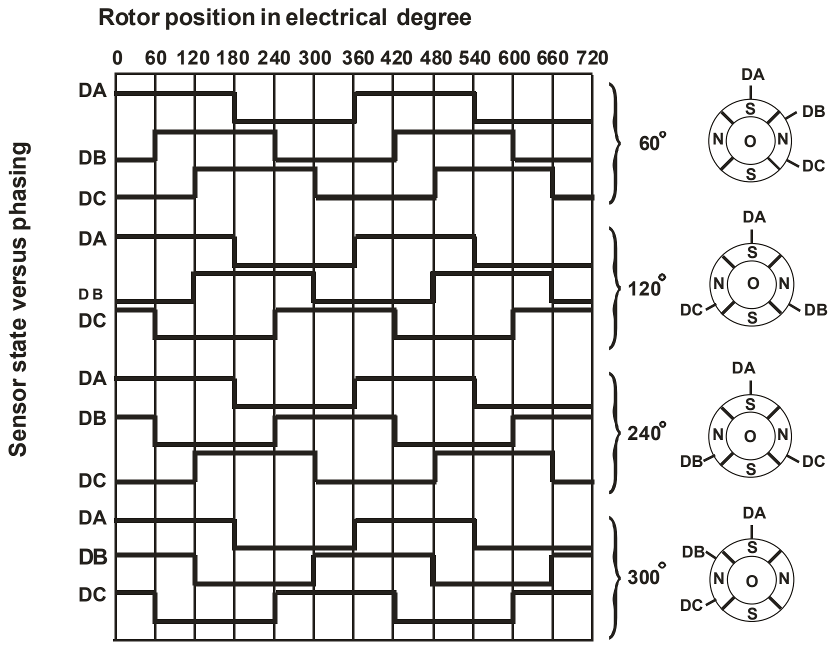


Figure 3 – Diagram of position sensor states

Algorithms 60° and 300° or 120° and 240° are symmetric but rotor rotation direction is opposite for it.

For example, when signals' delivering of rotor position sensor with phasing algorithm 60° or 120° to inputs «DA», «DB», «DC», the module will give current control signal for forward rotation, and when signals' delivering of rotor position sensor with phasing algorithm 240° or 300° - for backward rotation.

To change the direction of rotation of the engine allows the low-level signal (0) applied to the input of «Fwd/Back», while motor control current signals are inverted in accordance with Table 2.

Thereby using «60°/120°» and «Fwd/Back» instructions the module allows realizing any phasing algorithm from the introduced ones.

These algorithms correspond to the six of eight possible combinations of triply-discharging code.

Two code combinations are prohibited. When delivering wrong code combination for special phasing algorithm to inputs «DA», «DB», «DC» the module disconnects the transistors and gives the "Error" signal.

4.3 «ENABLE» signal may be used in case of motor rotation direction switch and for controlling of dynamic braking mode.

4.3.1 When changing of rotation direction, it is necessary to install low level signal (0) to input «ENABLE», therewith power transistors will be closed. After that the signal of rotation direction «Fwd/Back» should be changed.

Timing diagram of recommended sequence of signals delivery to inputs «ENABLE» and «Fwd/Back» is shown at Figure 4.

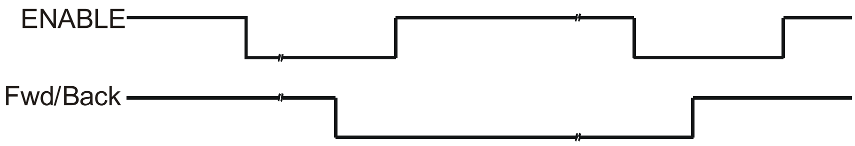


Figure 4

4.3.2. To driver the dynamic braking mode it is necessary to install low level signal to input "ENABLE", therewith power transistors will be closed. After that you should deliver pulses of required porosity to input "BRAKING" to open «low» transistors of three-phase inverter. The change of signal "BRAKING" porosity allows changing the hardness of dynamic braking mode.

The timing diagram of control signals of dynamic braking PWM-regulation is shown at Figure 5.

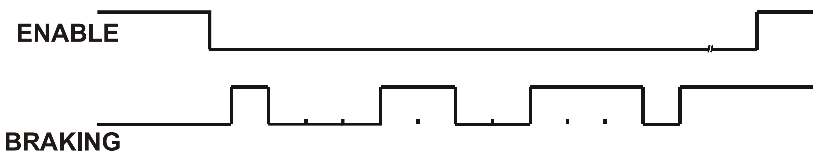


Figure 5

4.4 Input «BRAKING» underlies the other control inputs. High level signal delivery (1) provides the module transition to dynamic braking mode. Therewith «low» transistors of three-phase inverter that are connected to «+U_{com}» will be closed. «Low» transistors of three-phase inverter will open connecting all motor windings to «-U_{com}» (GND. MINUS). Thereby the windings are closed between that provides 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 source of reference voltage U_{ref} through resistor Rg and discharged through internal transistor. To decrease the level of acoustic noise and therewith provide effective level of current control signal of the motor you need to install the PWM generator frequency in the range of 20…30 kHz.

PWM generator frequency versus values Cg and Rg is shown at monogram of Figure 6b.
For instance, most effective generator frequency 25 kHz is set when choice of Cg=0.01 µF, Rg=4.7 kΩ.

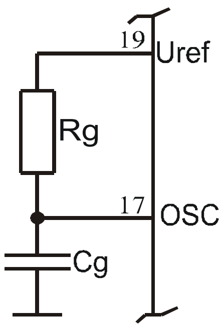


Figure 6a

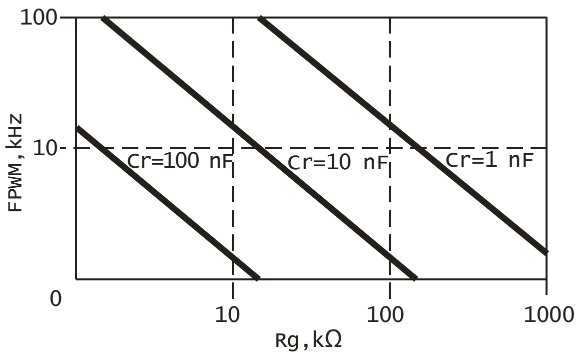


Figure 6b

4.6 When motor shaft rotating the electrical tachometer converts the signals "RPS" into pulse sequence of output signal "F TACH". Pulse repetition period corresponds to motor rotation speed, pulse duration t_p is controlled by value of Rt and Ct.
Connection circuit of Rt and Ct is shown at Figure 7a therewith maximum speed (in case of the use of internal FB) may be limited by the pulse duration Rt/Ct – chain, that is increase of t_p value decreases motor speed t_p =10/(NxA),

where N – motor speed, rpm;

A – recycle quantity of code combination per one motor shaft rotation.

To choice element Rt, Ct you need to use the monogram shown at Figure 7b.

For instance, if motor speed 5000 r/min, and there is 2 recycles of code sequences on the output "RPS" per a shaft rotation, then t_p= 1 ms.

For the chosen elements Rt =43 kΩ, Ct = 22 nF, pulse duration t_p = 950 µs.

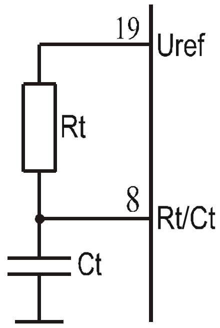


Figure 7a

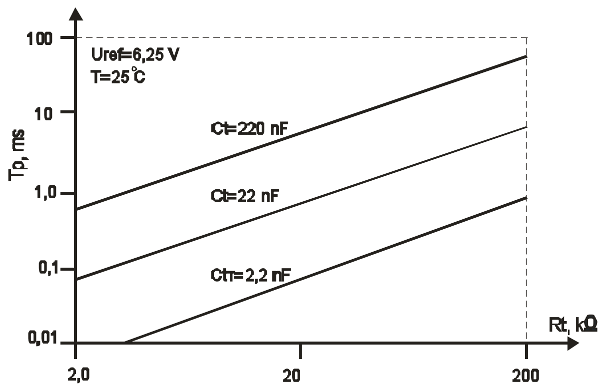


Figure 7b

4.7 The module controls the current value consumed from an external source on the internal current-measuring resistor (outputs «Rc+», «Rc-»). The signals from these outputs may be connected to current limitation circuit (inputs «Tc+», «Tc-») or used in an external current limitation circuit. The connection circuit is shown at Figure 8.

The additional elements R1, R2, C1 form LPF that prevent the hit of pulse noises to comparator input of current limitation circuit.

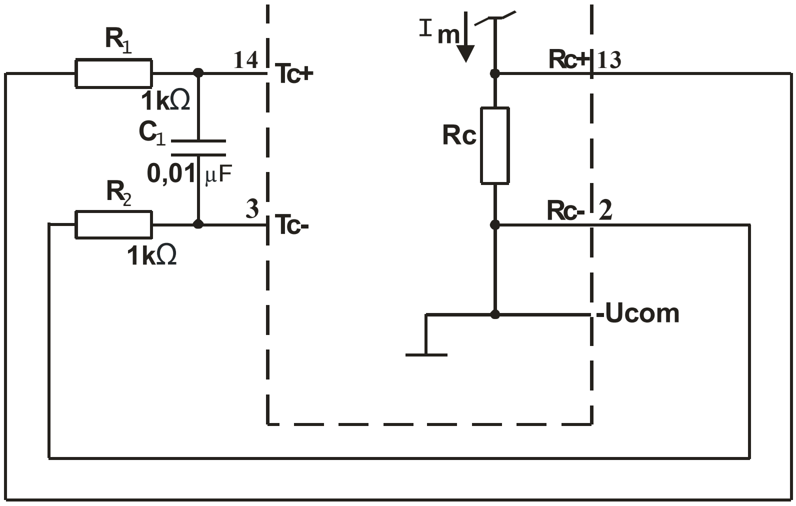


Figure 8

4.8 To regulate motor rotation speed the module is provided with the multiple unidirectional method, double-sided PWM that changes average voltage value applied to each motor stator winding during commutation cycle. Therewith the high transistor of three-phase inverter (that connects stator winding to «+U_{com}») is in the conducting state, the regulation is performed by low transistor switch (that connects stator winding to «-U_{com}»). The timing PWM-regulation diagram of motor speed is shown at Figure 9. As soon as the capacitor Cg of PWM generator is discharged the transistors of three-phase inverter is open giving the current to stator winding. If the level of increasing saw-tooth voltage of capacitor Cg will be more than the signal level on the PWM amplifier output («IN Tach2»), the low transistor of three-phase inverter will be closed interrupting the current in the supply circuit of motor stator winding. If the signal level on the PWM amplifier output («IN Tach2») increases the peak value of saw-tooth PWM generator voltage then the PWM-regulation will end, the motor rotates with maximum speed. PWM-regulation stops; the motor is rotated with maximum speed. If the level of current consumed by motor winding is more than the limiting value (on the inputs «Tc+», «Tc-» signal U>100 mV) then the transistors of three-phase inverter will be disconnected, low level (0) on the output "ERROR".

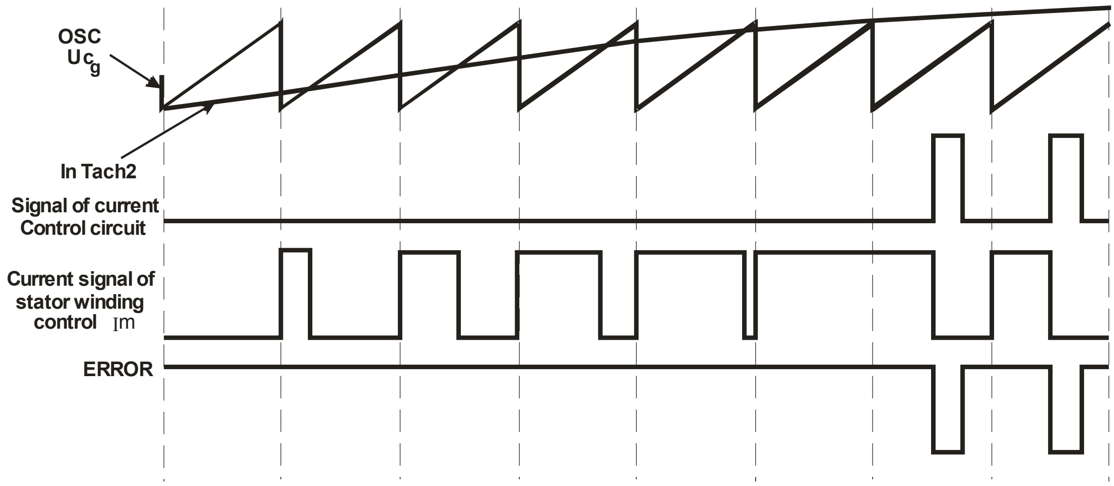


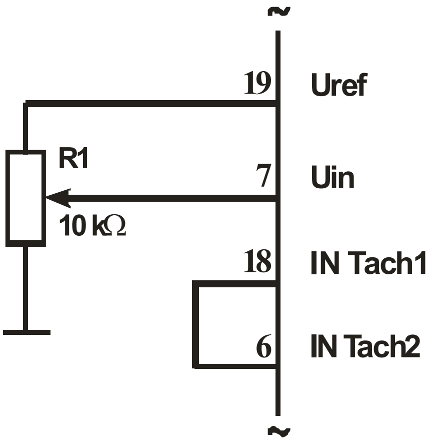
Figure 9 - PWM –regulation diagram of motor speed

4.9 The module can be used in the modes of open FB loop (when stabilization task and speed control task are determined by the other devices) and closed FB loop (when motor speed control in different functions is performed by module capabilities).

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

4.11 In case of module use in the mode of open FB loop the PWM-amplifier operates in mode of voltage follower.

Connection is shown at Figure 11.



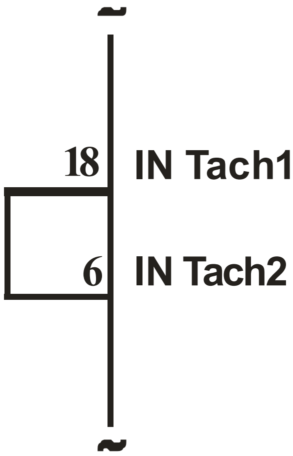
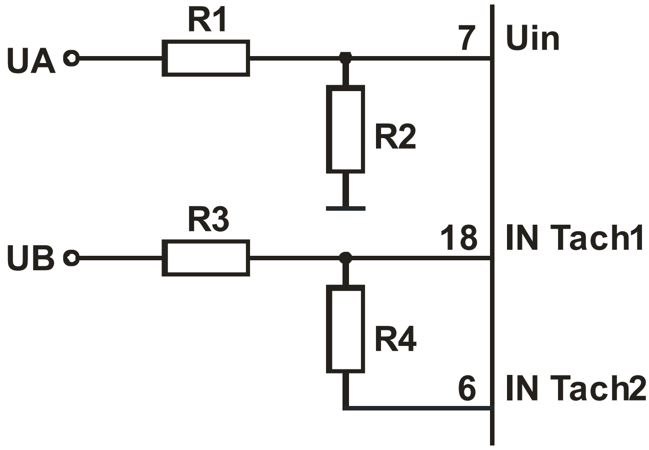
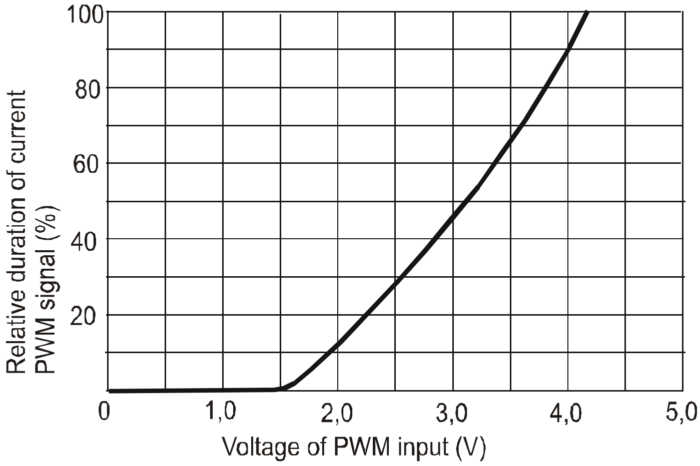


Figure 10

Figure 11

The version of speed control mode by two differential types is shown at Figure 12.
The duration of current control signal by motor winding versus voltage of PWM input is shown at Figure 13.





$$U_{IN\,Tach2} = U_A \times \left(\frac{R3+R4}{R1+R2}\right) \times \frac{R2}{R3} - \left(\frac{R4}{R3} \times UV\right)$$

Figure 12

Figure 13

4.12 The module can be used in mode of acceleration/deceleration controlling. The possible connection circuit is shown at Figure 14. Resistor R1 and capacitor C1 determines the constant of acceleration time, and R2 and C1 – the deceleration constant. The resistance values R1 and R2 should be lower than resistance value R3.

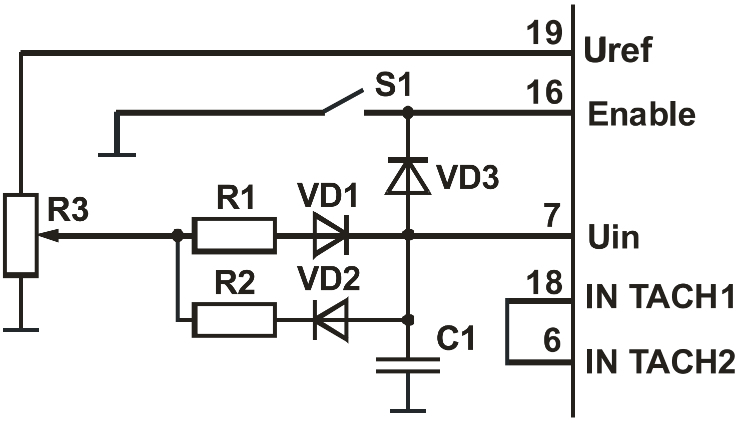


Figure 14

4.13 In case of the module use in the mode of close FB loop it is necessary to give FB PWM-signal to inverting amplifier input that is proportional to speed level.

The principle of FB signal generation is shown at Figure 15. This type of signal is generated by integration of electrical tachometer signal «F Tach». Connection circuit of integrator elements of proportional speed regulation (stabilization) is shown at Figure 16. If the elements are chosen correctly then the PWM integrator/amplifier will generate pulsation-free signal even if the motor speed is low. But in case of this schematic decision at the lowest speed the system response time will be worse. The rates of elements should be used in accordance with electro-mechanical motor characteristics. For these elements the time constant of integrator t=100 ms that allows getting good dynamic reaction and stability for application's majority.

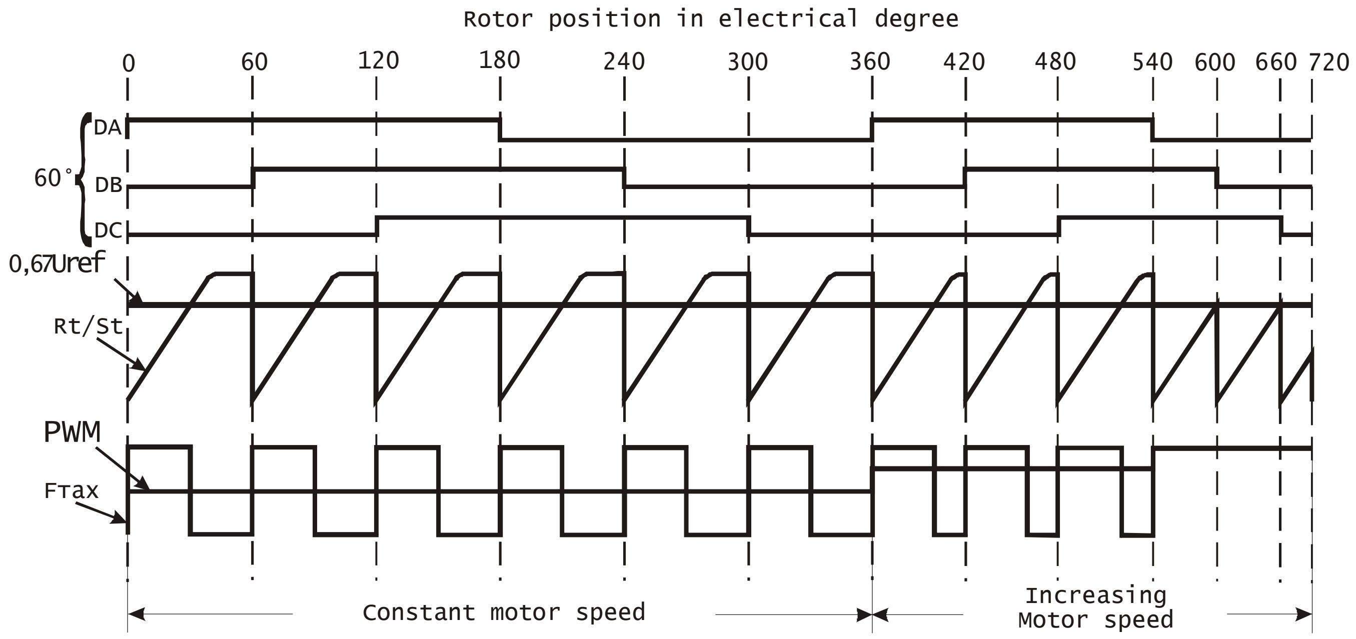


Figure 15 – FB signal forming of proportional speed control

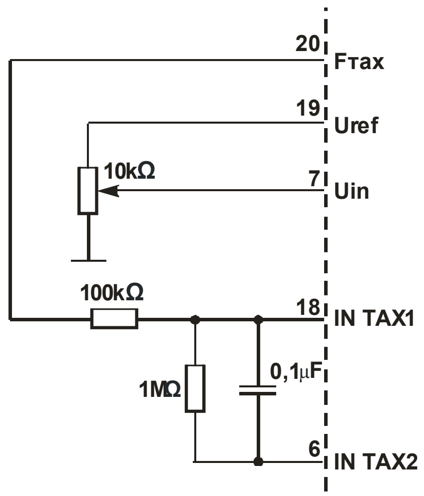


Figure 16

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