Phase Control Circuit–Load Current Feedback Applications

Description

The interated circuit, U210B1, is designed as a phase-control circuit for load-current feedback application in bipolar technology. To realize motor control systems, it has integrated load current detection, voltage monitoring and soft-start functions. The voltage obtained due to load current proportionality, can be used according to the application i.e., load-current compensation or load-current regulation.

Features

- Externally controlled integrated amplifier
- Variable soft start
- Automatic retriggering
- Voltage and current synchronization
- Triggering pulse typ. 125 mA
- Internal supply voltage monitoring
- Temperature constant reference source
- Current requirement ≤ 3 mA

Package: DIP14

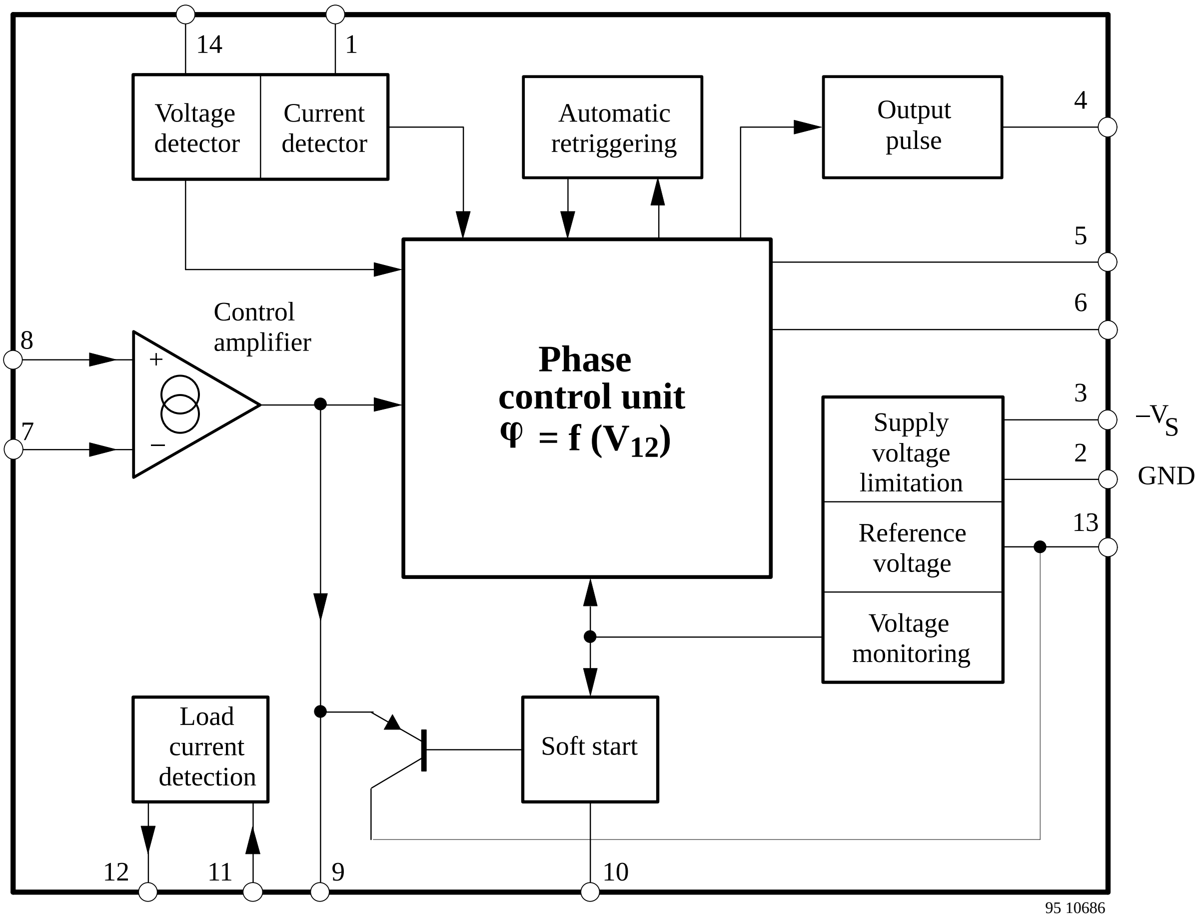


Figure 1. Block diagram

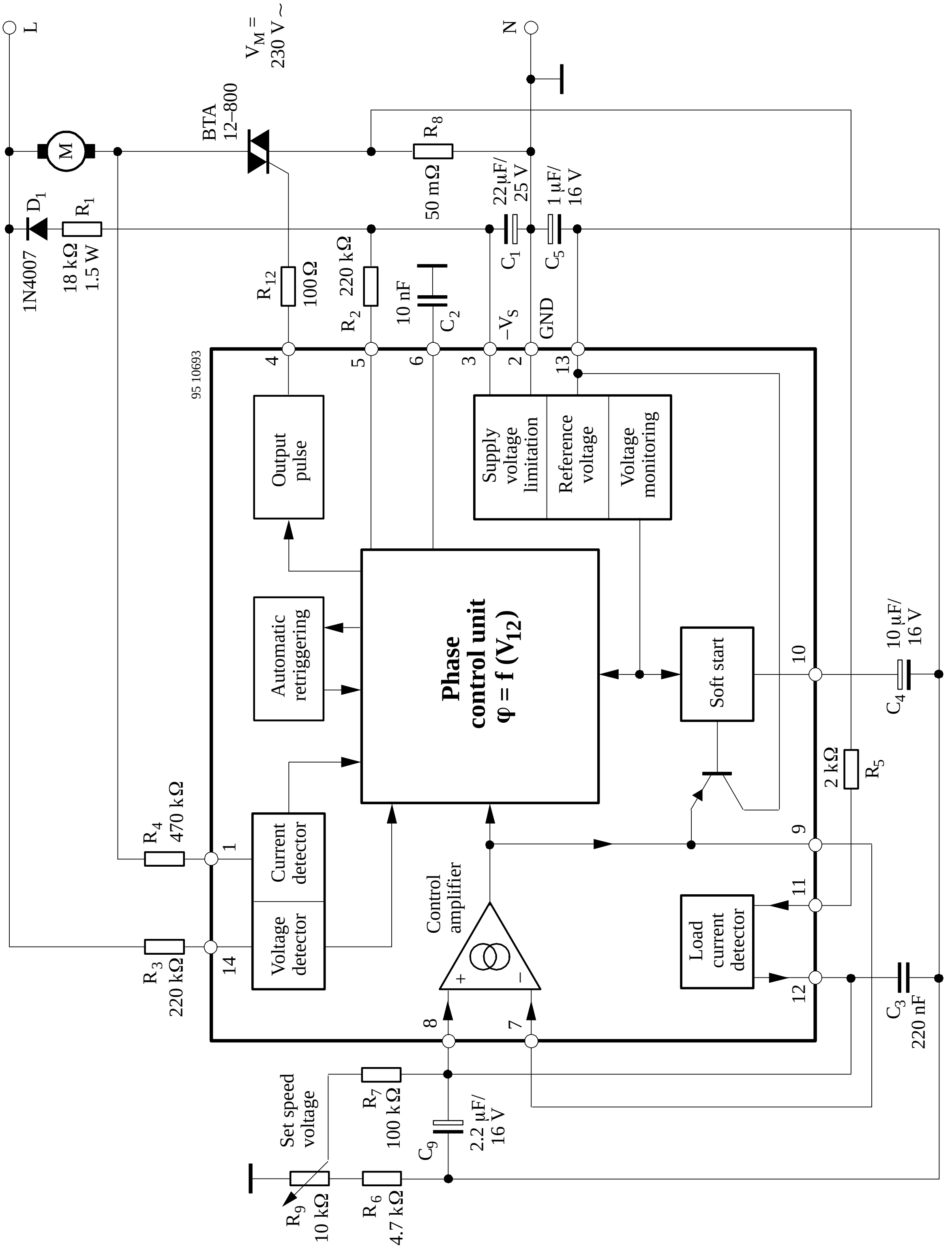


Figure 2. Block diagram with external circuitry Open loop control with load current compensation

Description

Mains Supply

The U210B1 is fitted with voltage limiting and can therefore be supplied directly from the mains. The supply voltage between Pin 2 (+pol/⊥) and Pin 3 builds up across D_1 and R_1 and is smoothed by C_1. The vaIue of the series resistance can be approximated using:

$$R_1 = \frac{V_M - V_S}{2\, I_S}$$

Further information regarding the design of the mains supply can be found in the data sheets in the appendix. The reference voltage source on Pin 13 of typ. –8.9 V is derived from the supply voltage. It represents the reference level of the control unit.

Operation using an externally stabiIised dc voltage is not recommended.

If the supply cannot be taken directly from the mains because the power dissipation in R_1 would be too large, then the circuit shown in the following figure 3 should be employed.

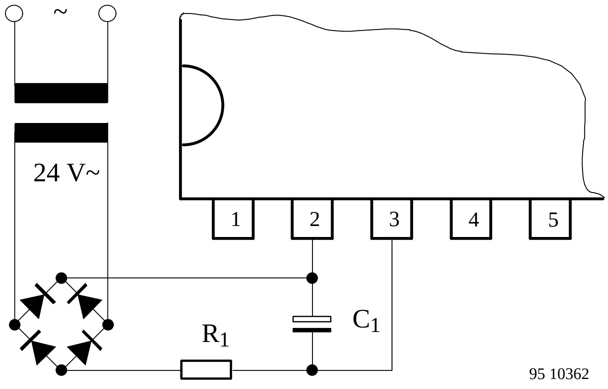


Figure 3. Supply voltage for high current requirements

Phase Control

The function of the phase control is largely identical to that of the well known component TEA1007. The phase angle of the trigger pulse is derived by comparing the ramp voltage, which is mains synchronized by the voltage detector, with the set value on the control input Pin 9. The slope of the ramp is determined by C_2 and its charging current. The charging current can be varied using R_2 on Pin 5. The maximum phase angle α_{max} can also be adjusted using R_2.

When the potential on Pin 6 reaches the nominal value predetermined at Pin 9, then a trigger pulse is generated whose width t_p is determined by the value of C_2 (the value of C_2 and hence the pulse width can be evaluated by assuming 8 µs/nF). At the same time, a latch is set, so that as long as the automatic retriggering has not been activated, then no more pulses can be generated in that half cycle.

The current sensor on Pin 1 ensures that, for operation with inductive loads, no pulse will be generated in a new half cycle as long as current from the previous half cycle is still flowing in the opposite direction to the supply voltage at that instant. This makes sure that “Gaps” in the load current are prevented.

The control signal on Pin 9 can be in the range 0 V to –7 V (reference point Pin 2).

If V_9 = –7 V then the phase angle is at maximum = α_{max} i .e. the current flow angle is a minimum. The minimum phase angle α_{min} is when $V_9 = V_2$.

Voltage Monitoring

As the voltage is built up, uncontrolled output pulses are avoided by internal voltage surveillance. At the same time, all of the latches in the circuit (phase control, soft start) are reset and the soft-start capacitor is short circuited. Used with a switching hysteresis of 300 mV, this system guarantees defined start-up behaviour each time the supply voltage is switched on or after short interruptions of the mains supply.

Soft-Start

As soon as the supply voltage builds up (t_1), the integrated soft-start is initiated. The figure below shows the behavior of the voltage across the soft-start capacitor and is identical with the voltage on the phase control input on Pin 9. This behaviour allows a gentle start-up for the motor.

C_4 is first charged with typ. 30 µA. The charging current then increases as the voltage across C_4 increases giving a progressively rising charging function with more and more strongly accelerates the motor with increasing rotational speed. The charging function determines the acceleration up to the set point. The charging current can have a maximum value of 85 µA.

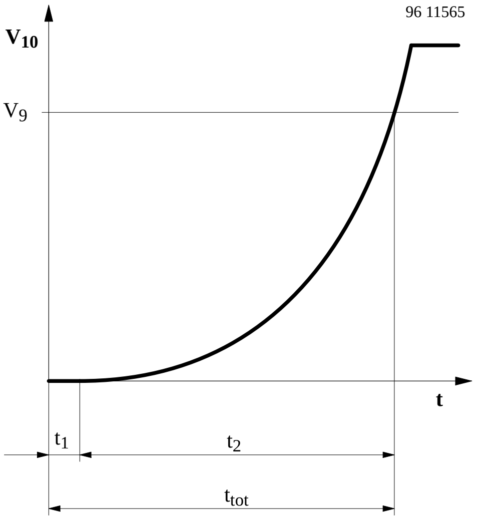


Figure 4. Soft–start

t_1 = build-up of supply voltage
t_2 = run-up time
t_{tot} = total start-up time to required speed

Control Amplifier

The integrated control amplifier with differential input has a bipolar current output, with typically ±110 µA at Pin 9 and a transmittance of typ. 1000 µA/V. The amplification and frequency response are determined by external circuit. For operation as a power control, it should be connected with Pin 7. Phase angle of the firing pulse can be adjusted by using the voltage at Pin 8. An internal limiting circuit prevents the voltage on Pin 9 becoming more negative than V_{13} + 1 V.

Load Current Detection, Figure 2

Voltage drop across R_8, dependent of load current, generates an input-current at Pin 11 limited by R_5. Proportional output current of 0.44 x I_{11} (CTR) is available at Pin 12. It is proportional with respect to phase and amplitude of load current.

Capacitor C_3 integrates the current whereas resistor R_7 evaluates it. The voltage obtained due to load current proportionality, can be used according to the application i.e., load current compensation or load current regulation.

Pulse Output Stage

The pulse output stage is short circuit protected and can typically deliver currents of 125 mA. For the design of smaller triggering currents, the function $I_{GT} = f (R_{GT})$ has been given in the data sheets in the appendix. In contrast to the TEA1007, the pulse output stage of the U210B1 has no gate bypass resistor.

Automatic Retriggering

The automatic retriggering prevents half cycles without current flow, even if the triac is turned off earlier e.g., due to not exactly centred collector (brush lifter) or in the event of unsuccessful triggering. After a time lapse of $t_{pp} = 4.5\ t_p$ is generated another triggering pulse which is repeated until either the triac fires or the half cycle finishes.

General Hints and Explanation of Terms

To ensure safe and trouble-free operation, the following points should be taken into consideration when circuits are being constructed or in the design of printed boards.

- The connecting lines from C_2 to Pin 6 and Pin 2 should be as short as possible, and the connection to Pin 2 should not carry any additional high current such as the load current. When selecting C_2, a low temperature coefficient is desirable.

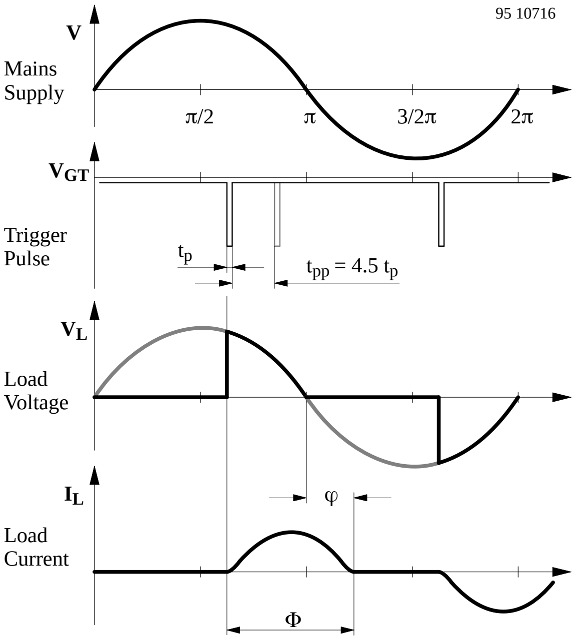


Figure 5. Explanation of terms in phase relationship

Absolute Maximum Ratings

Reference point Pin 2, unless otherwise specified

Parameters		Symbol	Value	Unit
Current requirement	Pin 3	$-I_S$	30	mA
t ≤ 10 µs		$-i_S$	100	
Synchronisation current	Pin 1	$-I_{sync.I}$	5	mA
	Pin 14	$-I_{sync.V}$	5	
t ≤ 10 µs	Pin 1	$-i_I$	35	
t ≤ 10 µs	Pin 14	$\pm i_v$	35	
Load current monitoring				
Input current	Pin 11	$-I_I$	2	mA
t ≤ 10 µs	Pin 11	$-I_I$	5	
Phase control				
Input voltage	Pin 9	$-V_I$	0 to 7	V
Input current	Pin 9	$\pm I_I$	500	µA
	Pin 5	$-I_I$	1	mA
Soft–start				
Input voltage	Pin 10	$-V_I$	$\lvert V_{13}\rvert$ to 0	V
Pulse output				
Reverse voltage	Pin 4	V_o	V_S to 5	V
Amplifier				
Input voltage	Pin 8	V_I	0 to V_S	
	Pin 7	$-V_I$	$\lvert V_{13}\rvert$ to 0	V
Reference voltage source				
Output current	Pin 13	I_o	7.5	mA
Storage temperature range		T_{stg}	–40 to +125	°C
Junction temperature		T_j	125	°C
Ambient temperature range		T_{amb}	–10 to +100	°C

Thermal Resistance

Parameters		Symbol	Value	Unit
Junction ambient	DIP14	R_{thJA}	120	K/W

Electrical Characteristics

$-V_s$ = 13 V, T_{amb} = 25°C, reference point Pin 2, unless otherwise specified

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
Supply voltage for mains operations	Pin 3	$-V_S$	13.0		V_{Limit}	V
Supply voltage limitation	$-I_S$ = 3 mA Pin 3	$-V_S$	14.6		16.6	V
	$-I_S$ = 30 mA		14.7		16.8	
DC supply current	$-V_S$ =13 V Pin 3	$-I_S$	1.2	2.5	3.0	mA
Reference voltage source	$-I_L$ = 10 µA Pin 13	$-V_{Ref}$	8.6	8.9	9.2	V
	$-I_L$ = 5 mA		8.3		9.1	
Temperature coefficient	Pin 13	$-TC_{VRef}$		0.5		mV/K
Voltage monitoring						
Turn-on threshold	Pin 3	$-V_{SON}$		11.2	13.0	V
Turn-off threshold	Pin 3	$-V_{SOFF}$	9.9	10.9		V

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
Phase control currents						
Current synchronization	Pin 1	$I_{sync.I}$	0.35		3.5	mA
Voltage synchronization	Pin 14	$I_{sync.V}$	0.35		3.5	
Voltage limitation	$\pm I_S$= 5 mA Pin 1 Pin 14	$\pm V_I$ $\pm V_I$	8.0 8.0	8.9 8.9	9.5 9.5	V
Reference ramp, figure 6						
Load current	$I_6 = f(R_F)$ Figure 6 R_f = 1 K ... 820 KΩ Pin 6	I_6	1		20	µA
R_φ–reference voltage	α ≥ 180 ° Pin5,3	$V_{\varphi Ref}$	1.06	1.13	1.18	V
Temperature coefficient	Pin 5	$TC_{V\varphi Ref}$		0.5		mV/K
Pulse output, figure 11						
Output pulse current	R_{GT}= 0, V_{GT}=1.2 V Pin 4	I_o	100	125	150	mA
Reverse current	Pin 4	I_{or}		0.01	3.0	µA
Output pulse width	C_φ = 10 nF Pin4,2	t_p		80		µs
Automatic retriggering						
Repetition rate	Pin 4	t_{pp}	3	4.5	6	t_p
Amplifier						
Common mode voltage range	Pin7,8	$V_{7,8}$	V_{13}		–1	V
Input bias current	Pin 8	I_{IB}		0.01	1	µA
Input offset voltage	Pin7,8	V_{IO}		13		mV
Output current	Figure 9 Pin 9	$-I_O$ $+I_O$	75 88	110 120	145 165	µA
Short circuit forward transmittance	$I_{12} = f(V_{10-11})$ Pin 9	Y_f		1000		µA/V
Soft-start, figures 7, 8 Pin 10						
Starting current	$V_{10} = V_{13}$	I_O	20	30	50	µA
Final current	V_{10} = –0.5 V	I_O	50	85	130	µA
Discharge current, restart pulse		$-I_O$	0.5	3	10	mA
Load current detection, figure 10 Pin 11						
Input current voltage	 V_I = 300 mV, R_1 = 1 KΩ	I_I I_I	0 300		500 308	µA µA
Input offset voltage		V_{IO}	–8		0	mV
Output open current	V_I = 0 V, R_1= 1 KΩ Pin 12	I_O	1.9		5.5	µA
Output current	V_I = 300 mV, R_1 = 1 KΩ $V_{12} = V_{13}$ Pin 12	I_O	120	127	134	µA
Current transfer ratio $CTR = \frac{I_{12}}{I_{11}}$	I_{12} = 150 µA Pin 12/11 I_{12} = 300 µA Pin 12/11	CTR		0.44 ± 5% 0.42 ± 6%		
Temperature coefficient of current transfer ratio	Pin 12/11	TC		0.2		$^0/_{00}$/K

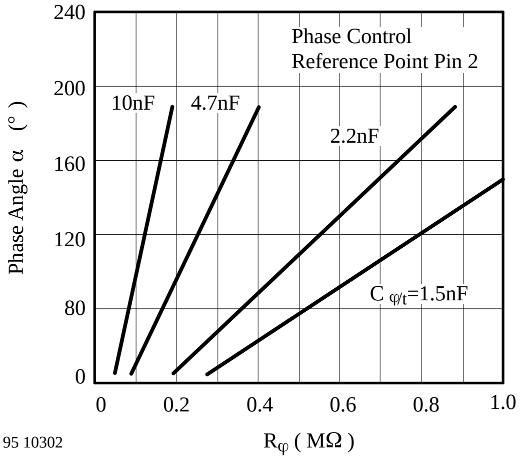


Figure 6.

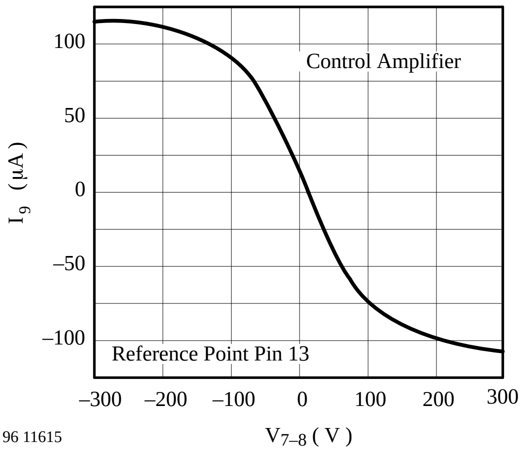


Figure 9.

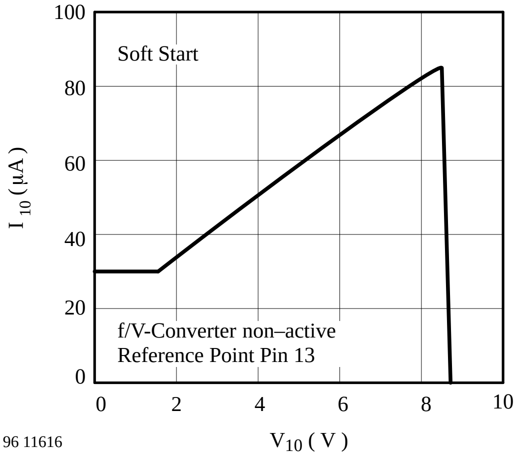


Figure 7.

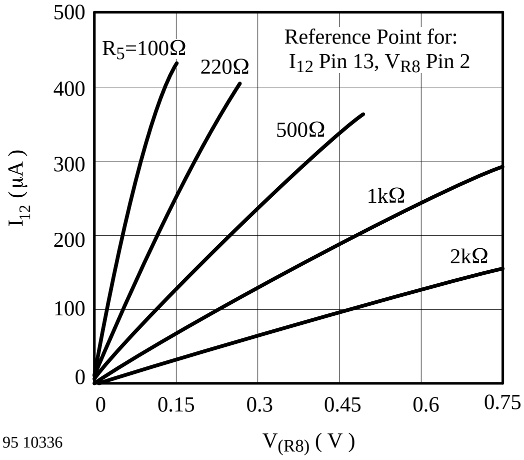


Figure 10.

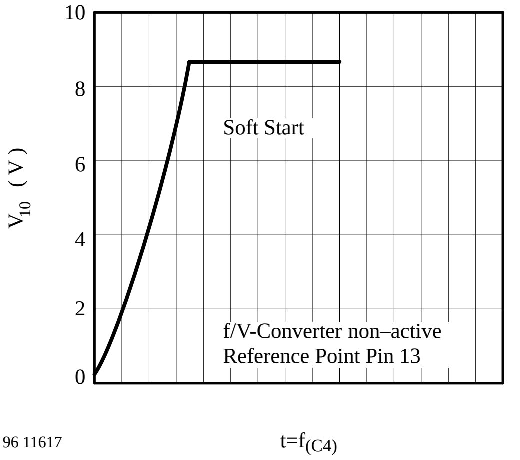


Figure 8.

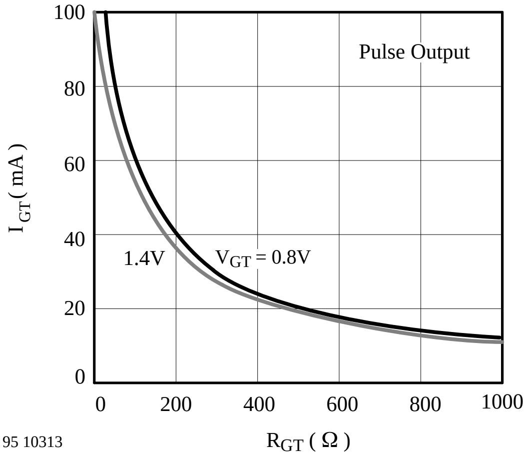


Figure 11.

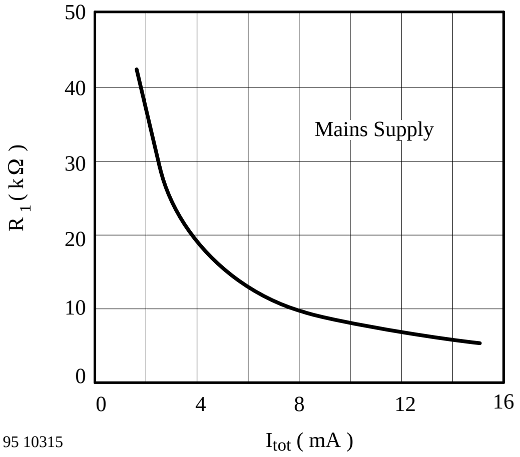


Figure 12.

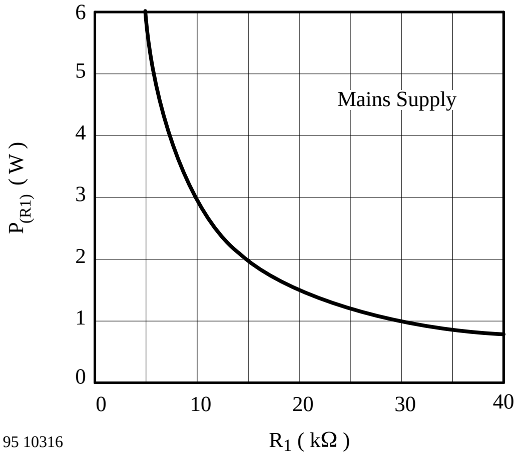


Figure 13.

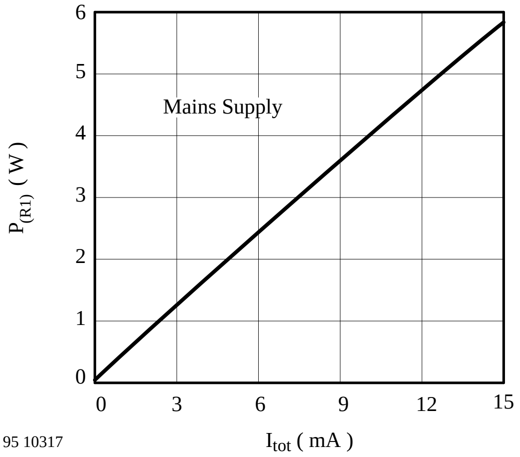


Figure 14.

Design Calculations for Mains Supply

The following equations can be used for the evaluation of the series resistor R_1 for worst case conditions:

$$R_{1max} = 0.85 \frac{V_{Mmin} - V_{Smax}}{2\ I_{tot}} \qquad R_{1min} = \frac{V_M - V_{Smin}}{2\ I_{Smax}}$$

$$P_{(R1max)} = \frac{(V_{Mmax} - V_{Smin})^2}{2\ R_1}$$

where:

V_M = Mains voltage, 230 V∼
V_S = Supply voltage on Pin 3
I_{tot} = Total DC current requirement of the circuit
= $I_{Smax} + I_p + I_x$
I_{Smax} = Current requirement of the IC in mA
I_p = Average current requirement of the triggering pulses
I_x = Current requirement of other peripheral components

R_1 can be easily evaluated from the diagrams figures 12 to 14.

Applications

In contrast to simple speed controller, the circuits shown in figures 15 and 16, react to the load dependent speed drop in which the magnitude of the load current acts on the speed compensation.

For this purpose, the load current is measured by shunt resistor R_8. The voltage drop generates a current at Pin 11 dependent of R_5, which reflects in the specified current at the output of Pin 12.

Rated impedance of the output current at Pin 12 is represented through the coupling resistance R_7 and the total impedance of the set point.

The integrated load current proportional signal at C_3 effects in the same direction on the control input as the set point i.e., by the increase of load current follows an automatic increase of manipulated set point, so that a compensation of speed falls.

Compensation arrangement is influenced with resistance values i.e. R_5 (= 100 to 5 kΩ) and R_7 (= 10 kΩ to 150 kΩ) whereas the higher effect is achieved by increasing the value of R_7 and decreasing R_5. Influence of compensation can be increased up to the value where the drive system (motor) starts to oscillate.

Dimensioning in the applications are with the drill machine of 700 W power.

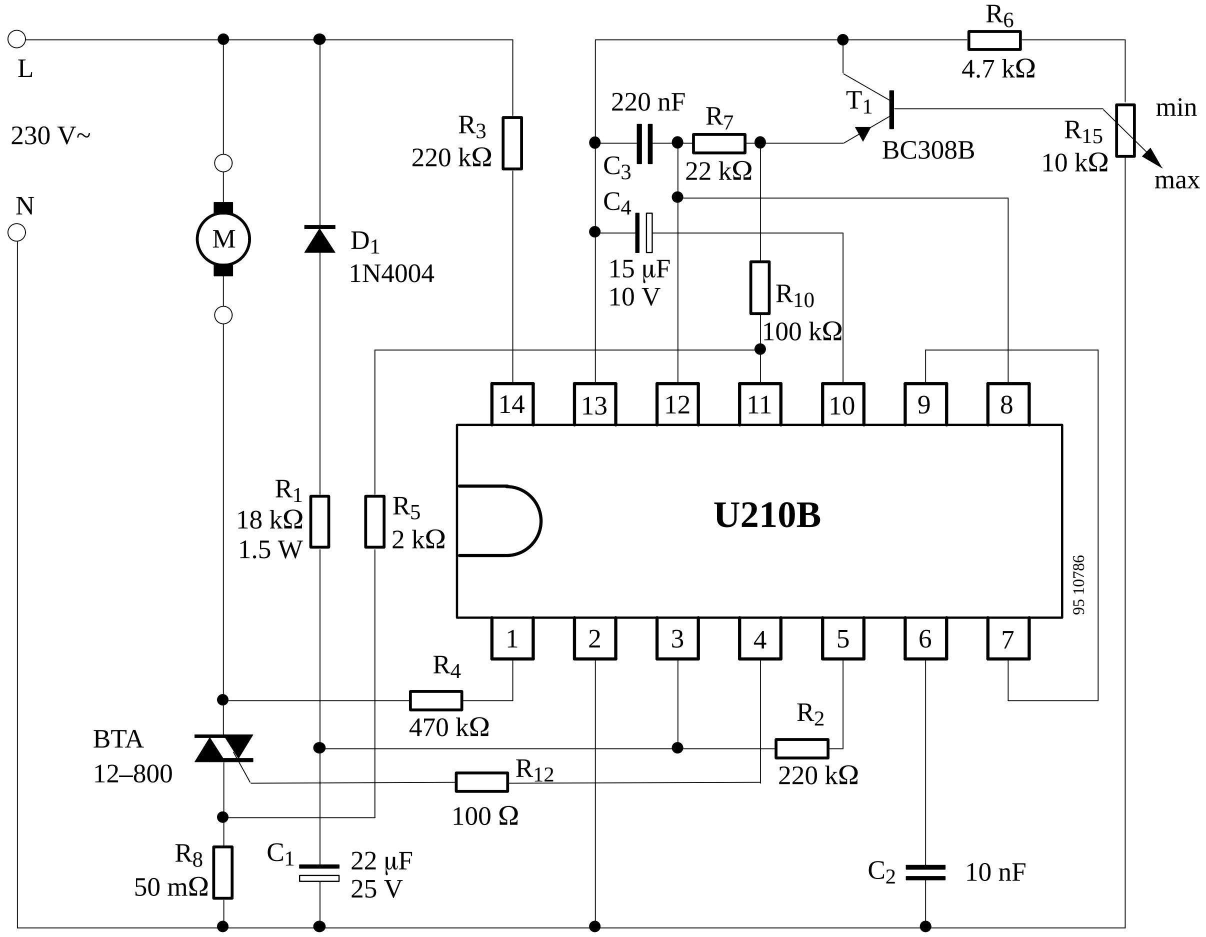


Figure 15. Speed control with load current compensation

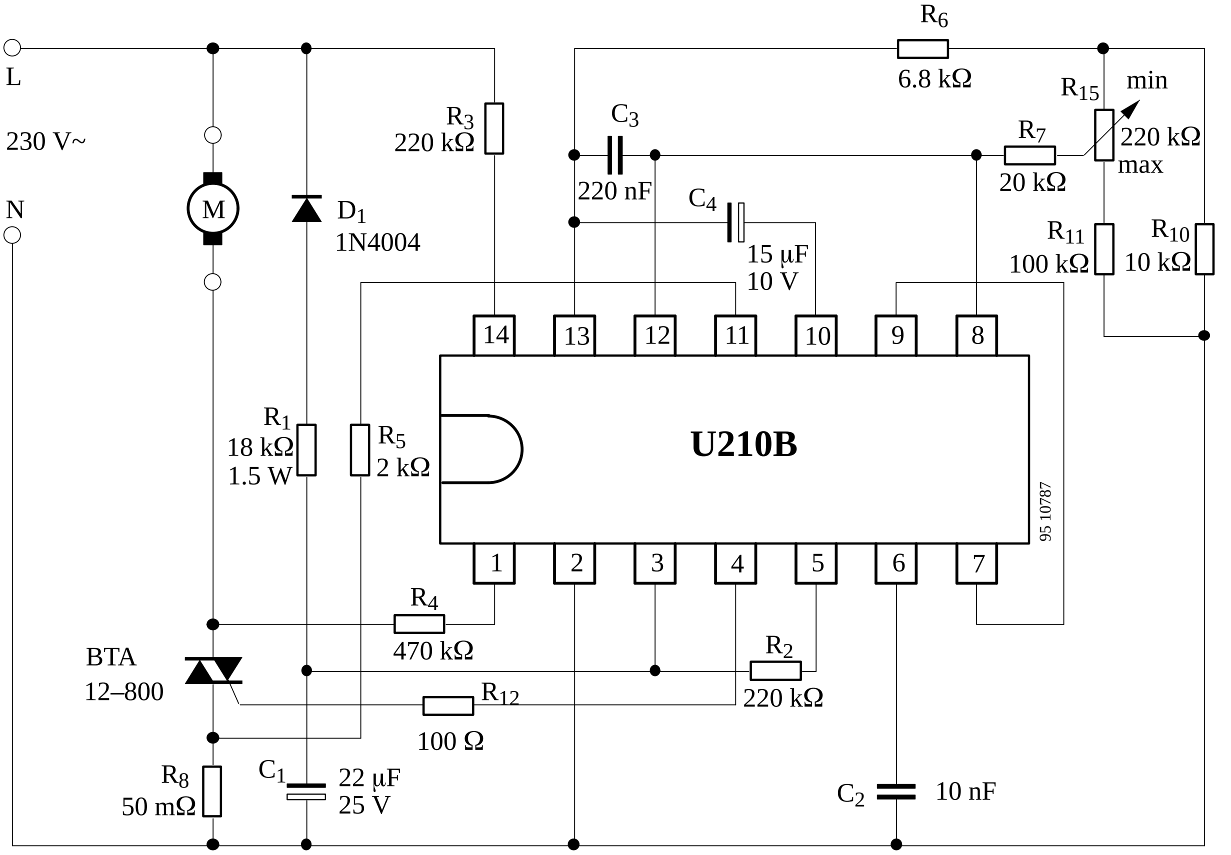


Figure 16. Speed control with load current compensation

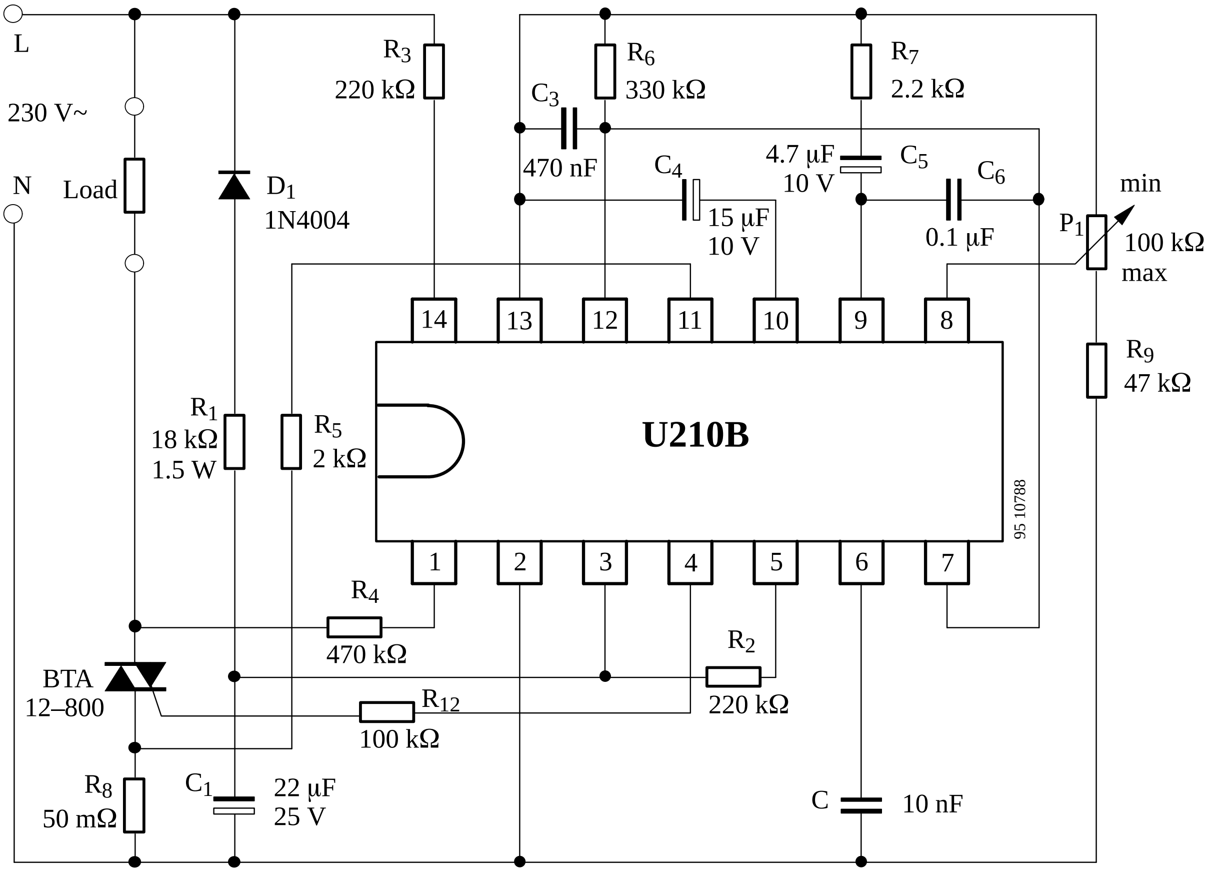


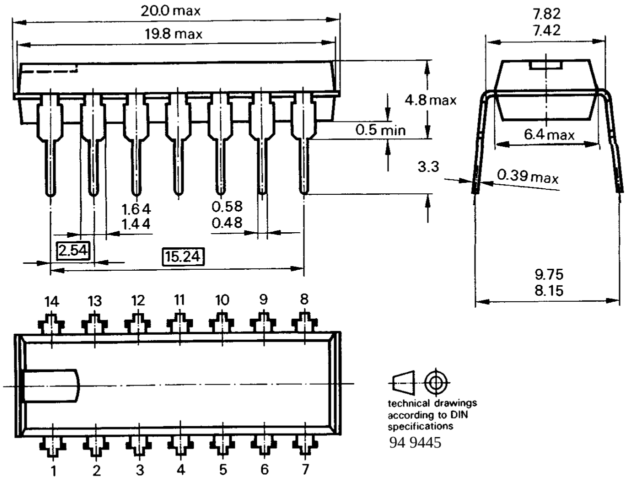
Figure 17. Load current regulation with soft start

Current regulation is achieved by the integrated operational amplifier as P_1-controller (R_7, C_5, C_6). Inverted input (Pin 7) of the operational amplifier is directly connected at C_3 with load current proportional test signal (actual value).

Desired value is obtained with the help of potentiometer at Pin 8.

Dimensions in mm

Package: DIP14



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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.

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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.

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