

**TLE 3101
TLE 3102
TLE 3103
TLE 3104**

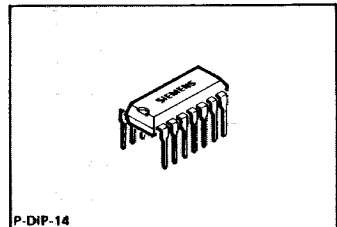
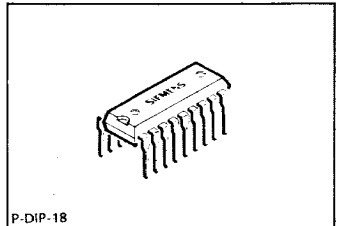
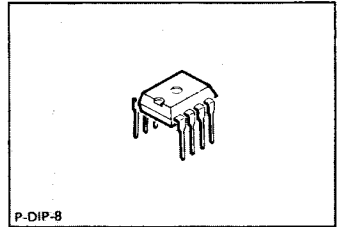
Bipolar IC

Features

- Direct supply from ac line possible
- Low power consumption, typically 2.4 mA
- Only one capacitor for trigger pulse width and phase angle
- Highly stabilized reference voltage
- Negative triac gate trigger current, 100 mA max.
- No triac drive pulses during supply undervoltage
- Optional voltage or current synchronization
- TLE 3101 with independent on-chip op amp OP and comparator K3

The following versions were produced from that basic IC:

- TLE 3102 without comparator K3
- TLE 3103 without op amp
- TLE 3104 without K3, enable input E/A, control input $V_{control}$, and without Z diode output



| Type | Ordering Code | Package |
|--------------|---------------|----------|
| ☐ TLE 3101 | Q67000-A2337 | P-DIP-18 |
| ■ ☐ TLE 3102 | Q67000-A2338 | P-DIP-14 |
| ■ ☐ TLE 3103 | Q67000-A2339 | P-DIP-14 |
| ☐ TLE 3104 | Q67000-A2312 | P-DIP-8 |

■ = Not for new design

These simplified versions are provided for less complex low-cost applications.

These bipolar phase control ICs require, for most applications, only a minimum number of external components. Typical applications are motor control, brightness control, temperature control, $\cos \varphi$ optimization for squirrel-cage motors, and starting current limitation.

Thanks to their high efficiency, the TLE 310 x ICs are particularly suitable for consumer goods, such as kitchen appliances and washing machines, vacuum cleaners, electric irons and hobbyist appliances.

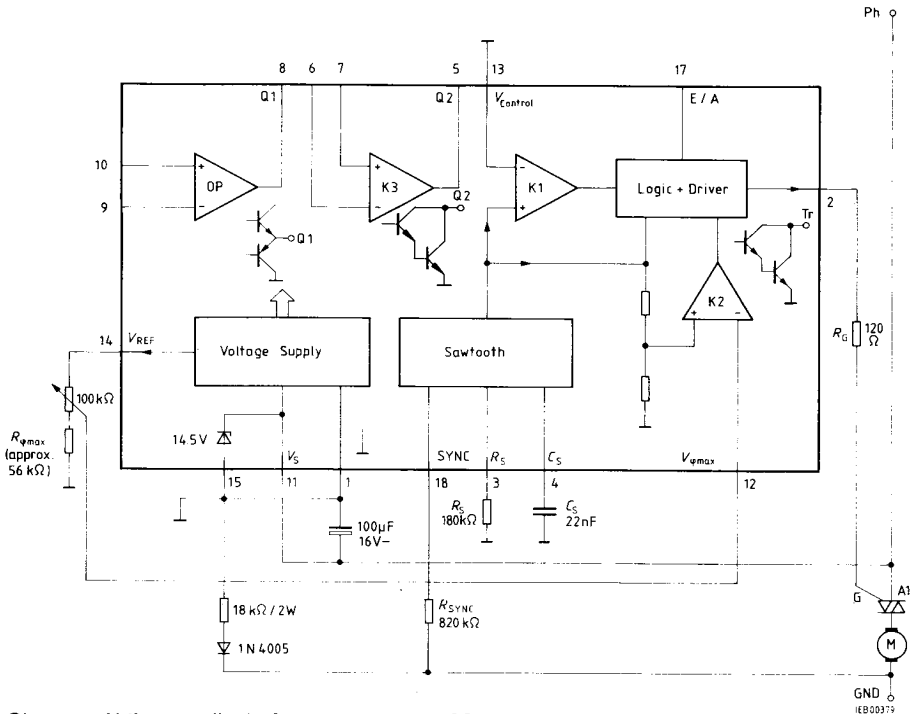
A special feature is the soft start which requires only straightforward wiring, and is e.g. used in portable drills for center punching.

Pin Definitions and Functions for TLE 3101

| Pin | Function | Pin | Function |
|-----|----------------------|-----|------------------------------|
| 1 | Ground | 10 | + input op amp |
| 2 | Triac trigger output | 11 | V_S |
| 3 | R_S | 12 | $V_{\phi_{max}}$ |
| 4 | C_S | 13 | $V_{control}$, K1 |
| | | 14 | V_{REF} |
| 5 | Output Q2, K3 | 15 | Z diode |
| 6 | -input K3 | 16 | N.C. |
| 7 | +input K3 | 17 | Enable input E/A |
| 8 | Output Q1, op amp | 18 | Synchronization input (SYNC) |
| 9 | -input op amp | | |

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Block Diagram with External Components for Motor Control

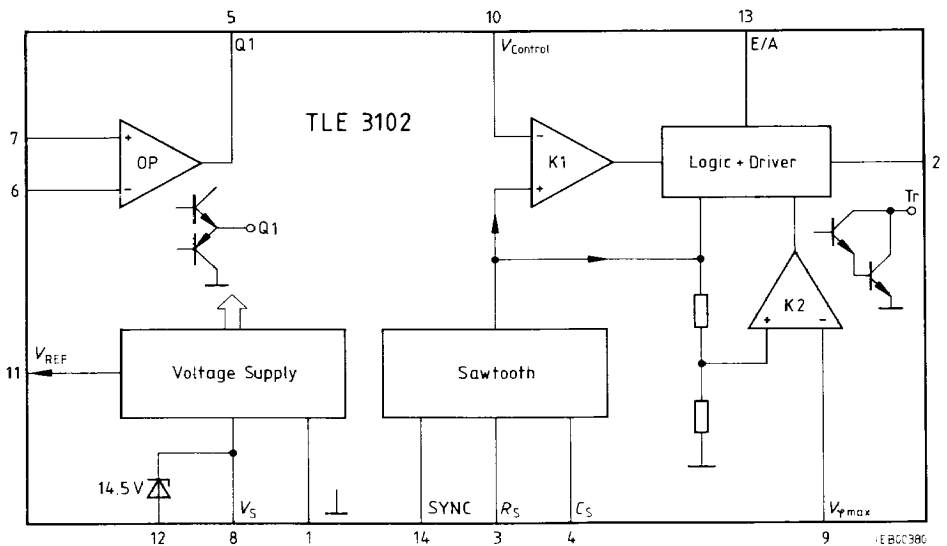


The TLE 3102 with on-chip op amp for external use is particularly suitable as a speed controller with P, PI, or PID characteristic; the op amp serves as adjustable gain amplifier. An actual value which is proportional to speed can be formed by rectification of the tachometer amplitude.

Pin Definitions and Functions for TLE 3102

| Pin | Function | Pin | Function |
|-----|----------------------|-----|------------------------------|
| 1 | Ground | 8 | V_S |
| 2 | Triac trigger output | 9 | $V_{\phi \max}$ |
| 3 | R_S | 10 | V_{control} K1 |
| 4 | C_S | 11 | V_{REF} |
| 5 | Output Q1, op amp | 12 | Z diode |
| 6 | -input op amp | 13 | Enable input E/A |
| 7 | +input op amp | 14 | Synchronization input (SYNC) |

Block Diagram



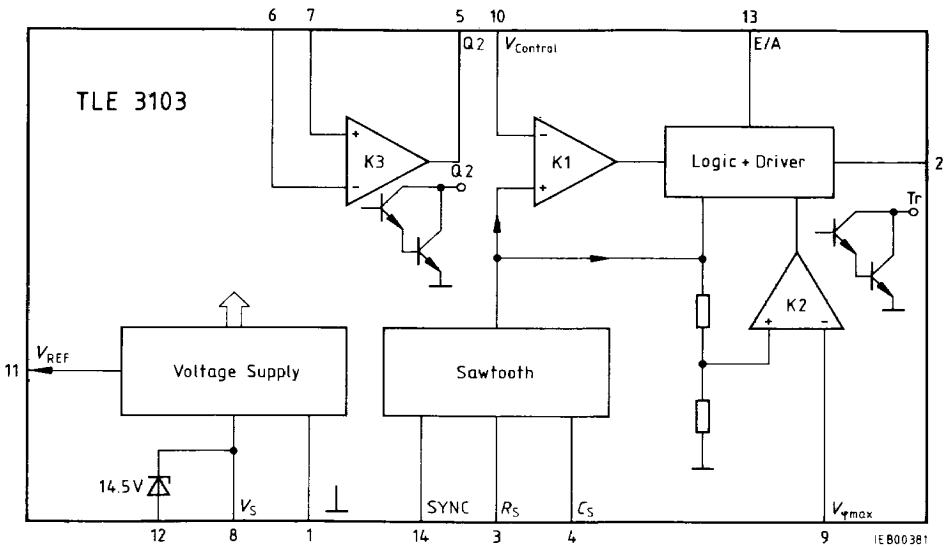
The TLE 3103 with on-chip comparator for external use is particularly suitable for phase control systems in which special functions, such as blocking protection or overtemperature protection, are required.

Pin Definitions and Functions for TLE 3103

| Pin | Function | Pin | Function |
|-----|----------------------|-----|------------------------------|
| 1 | Ground | 8 | V_S |
| 2 | Triac trigger output | 9 | $V_{\phi_{max}}$ |
| 3 | R_S | 10 | $V_{control}, K1$ |
| 4 | C_S | 11 | V_{REF} |
| 5 | Output Q2, K3 | 12 | Z diode |
| 6 | - Input K3 | 13 | Enable input E/A |
| 7 | + Input K3 | 14 | Synchronization input (SYNC) |

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Block Diagram

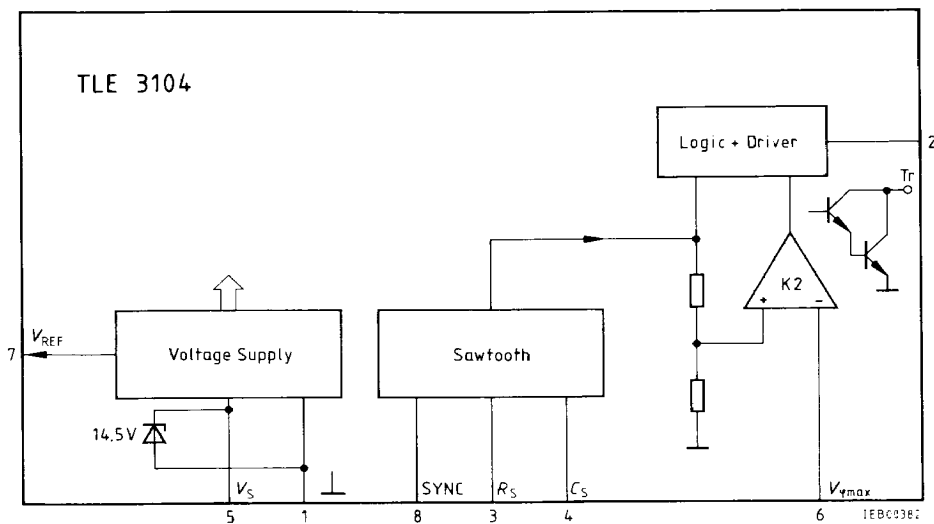


The TLE 3104 is particularly suitable for simple, low-cost phase control and motor control systems, in which the actual value is formed by rectification of the tacho amplitude.

Pin Definitions and Functions for TLE 3104

| Pin | Function | Pin | Function |
|-----|----------------------|-----|------------------------------|
| 1 | Ground | 5 | V_S |
| 2 | Triac trigger output | 6 | $V_{\phi_{max}}$ |
| 3 | R_S | 7 | V_{REF} |
| 4 | C_S | 8 | Synchronization input (SYNC) |

Block Diagram



Functional Description

The following is a description of the individual functional units (refer to block diagram) and their interactions:

Operational Amplifier op amp

Two inputs and the output are available. The op amp is internally compensated and has a push-pull output. Should the op amp not be required, the +input must be connected to ground (the TLE 3101 and TLE 3102 then consume minimum current).

Comparator K 3

Comparator K3 is not frequency-compensated. The output is an open NPN collector which in switching operation may drive an LED, for example. Should the comparator not be required, the -input must be connected to ground. K3 then has minimum current consumption.

Reference Voltage Source

A temperature-stabilized voltage source is available for control and regulating circuits.

Sawtooth Generator

In this unit, a sawtooth synchronized to the line is generated by the external R_S and C_S . The phase angle of the triac is determined by comparison of the sawtooth voltage and the control voltage. The trigger pulse width for the driver is provided by the falling edge of the sawtooth generator. The charge of C_S determines the trigger pulse width. A special circuit ensures the release of only one trigger pulse per line half period.

Comparators K1, K2

Sawtooth voltage and control voltage are compared by means of comparators K1 and K2. Comparator K2 receives only half the sawtooth voltage. The phase angle limit can be adjusted within the complete phase angle range by applying a reduced reference voltage to input " $V_{\phi_{max}}$ ". Comparator K2 provides starting current limitation and/or phase angle limitation for inductive loads. Both comparator outputs are fed to the logic and driver unit.

The comparator with the smaller conduction angle is the dominating one. With $V_{\phi_{max}}$ dominating, the trigger pulse width is doubled – compared with the trigger pulse width in case of a dominating $V_{control}$.

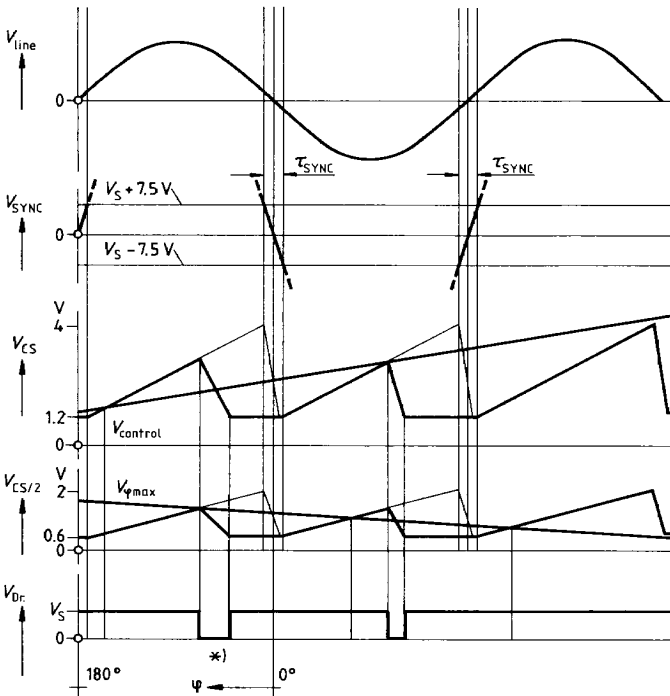
Logic + Driver

The logic and driver unit for triac triggering is controlled by comparators K1, K2, and the enable input E/A. The E/A input is TTL-compatible and may disable or enable the trigger pulse. Logic + driver obtain information on the trigger pulse width from the sawtooth. The undervoltage monitoring enables the driver output only if the IC's supply voltage has reached the permissible minimum value. The driver output to the triac supplies negative pulses.

Synchronization

At the sync input, the phase angle is synchronized to the zero crossing point of the line voltage. The sync pulse width τ_{SYNC} has to be twice as large as the trigger pulse width.

Pulse Diagram



Conduction angle (with resistive load)

*) With $V_{\varphi_{\text{max}}}$ dominating, the trigger pulse width is doubled.

Absolute Maximum Ratings

$T_A = -25$ to 85 °C

| Parameter | Symbol | Limit Values | | Unit |
|---|------------------|--------------|-------|------|
| | | min. | max. | |
| Supply voltage | V_S | -0.3 | 33 | V |
| Inputs op amp K3 | V_I | -0.3 | 33 | V |
| Output op amp | V_{Q1} | -0.3 | V_S | V |
| Output K3 (disabled) (enabled) | I_{Q1} | -5 | 3 | mA |
| | V_{Q2} | -0.3 | 33 | V |
| | I_{Q2} | 0 | 40 | mA |
| Output V_{REF} | V_{REF} | -0.3 | 5 | V |
| Z diode | I_Z | -35 | 35 | mA |
| Input SYNC | I_{SYNC} | -10 | 10 | mA |
| Input R_S | V_{RS} | -0.3 | 5 | V |
| Input C_S | V_{CS} | -0.3 | 5 | V |
| Input $V_{control}$ | $V_{control}$ | -0.3 | V_S | V |
| Input $V_{\phi_{max}}$ | $V_{\phi_{max}}$ | -0.3 | V_S | V |
| Enable input E/A | $V_{E/A}$ | -0.3 | 33 | V |
| Output driver (disabled) | $V_{Q\ dr}$ | -0.3 | 33 | V |
| (enabled) | $I_{Q\ dr}$ | 0 | 120 | mA |
| Total power dissipation (time integral) | P_{tot} | | 700 | mW |
| Junction temperature | T_j | | 150 | °C |
| Storage temperature | T_{stg} | -55 | 125 | °C |
| Thermal resistance system – air | | | | |
| P-DIP- 8 – TLE 3104 | $R_{th\ SA}$ | | 100 | K/W |
| P-DIP-14 – TLE 3102, TLE 3103 | $R_{th\ SA}$ | | 70 | K/W |
| P-DIP-18 – TLE 3101 | $R_{th\ SA}$ | | 70 | K/W |

Operating Range

| | | | | |
|---------------------|------------|------|-----|----|
| Supply voltage | V_S | 10 | 30 | V |
| Ambient temperature | T_A | -25 | 85 | °C |
| Input SYNC | I_{SYNC} | -3.5 | 3.5 | mA |

Characteristics

$V_S = 10$ to 30 V, $T_V = -25$ to 85 °C

| Parameter | Symbol | Limit Values | | | Unit | Test Conditions |
|---|---------------------------|--------------|------|------|------|-----------------|
| | | min. | typ. | max. | | |
| Current Consumption without output load at op amp, K3, driver, V_{REF} , without R_{SYNC} current | I_S | | 2.4 | 3.2 | mA | $V_S = 14.5$ V |
| Reference voltage | V_{REF} | 1.8 | 2.0 | 2.2 | V | |
| Load current | $-I_L$ | 0 | | 3 | mA | |
| Stability $V_S = 10$ to 30 V $I_{REF} = 0$ to 3 mA | ΔV_{REF} | | | 10 | mV | |
| | ΔV_{REF} | | | 20 | mV | |
| Temperature coefficient | $\Delta V_{REF}/\Delta T$ | -0.5 | | 0.5 | mV/K | |

Operational Amplifier op amp

| | | | | | | |
|---------------------------------|-------------|-----|-----|---------|---------|--|
| Open-loop voltage gain | G_{V0} | 60 | 90 | | dB | |
| Input offset voltage | V_{IO} | -10 | | 10 | mV | |
| Input current | $-I_I$ | | | 2 | μ A | |
| Common-mode input voltage range | V_{IC} | 0 | | V_S-3 | V | |
| Output current | I_{O1} | -3 | | 1.5 | mA | |
| Transition frequency | f_T | | 2 | | MHz | |
| Transition phase | φ_T | | 120 | | deg. | |
| Output voltage | V_{O1} | 1.0 | | V_S-3 | V | |

Comparator K3

| | | | | | | |
|---------------------------------|----------|-----|-----|---------|---------|-------------------------------------|
| Input current | $-I_I$ | | | 2 | μ A | |
| Input offset voltage | V_{IO} | -20 | | 20 | mV | |
| Output enabled disabled | V_{O2} | | 1.0 | 1.5 | V | $I_{O2} = 20$ mA $V_{O2} = 30$ V |
| | I_{O2} | | | 5 | μ A | |
| Common-mode input voltage range | V_{IC} | 0 | | V_S-3 | V | |

Input K1 ($V_{control}$)

| | | | | | | |
|--|--------|--|-----|-------------------|---------|--|
| Input current | $-I_S$ | | | 2 | μ A | |
| Control range: Conduction angle = 0° (dependent on R_S and C_S) Conduction angle = 175° Max. perm. conduction angle | | | 4 | | V | |
| | | | 1.2 | | V | |
| | | | | | deg. | |
| | | | | SYNC pulse end -5 | | |

Input K2 ($V\varphi_{max}$)

| | | | | | | |
|--|--------|--|-----|-------------------|---------|--|
| Input current | $-I_S$ | | | 2 | μ A | |
| Control range: Conduction angle = 0° (dependent on R_S and C_S) Conduction angle = 175° Max. perm. conduction angle | | | 2 | | V | |
| | | | 0.6 | | V | |
| | | | | | deg. | |
| | | | | SYNC pulse end -5 | | |

Characteristics

$V_S = 10\text{ V to }30\text{ V}$, $T_A = -25\text{ to }85\text{ }^\circ\text{C}$

| Parameter | Symbol | Limit Values | | | Unit | Test Conditions |
|----------------|--------|--------------|------|------|------|---------------------|
| | | min. | typ. | max. | | |
| Z Diode | | | | | | |
| Z voltage | V_Z | 13 | 14.5 | 16 | V | $I_Z = 5\text{ mA}$ |

Enable Input E/A

| | | | | | | |
|--|----------|-----|--|-----|---------------|--|
| Input current | $-I_I$ | | | 2 | μA | |
| H input voltage for driver output, active | V_{IH} | 2.8 | | | V | |
| L driver output disabled | V_{IL} | | | 0.8 | V | |

Triac Trigger Output

| | | | | | | |
|------------------|-------|-----|---|-----|---------------|--|
| Output, enabled | V_L | 1.4 | 2 | 2.5 | V | $I_Q = 10\text{ mA}$ 20 mA 50 mA 100 mA |
| | | 1.4 | 2 | 2.5 | V | |
| | | 1.4 | 2 | 3.0 | V | |
| | | 1.4 | 4 | 6.0 | V | |
| Output, disabled | I_Q | | | 10 | μA | $V_Q = 30\text{ V}$ |

Input SYNC

| | | | | | | |
|---|-------------------|-----|---------------|----|---------------|--|
| Switching current | I_{SYNC} | | ± 20 | | μA | |
| Switching threshold | V_{SYNC} | | $V_S \pm 7.5$ | | V | |
| Output disconnection at V_S undervoltage | V_S | 7.5 | 8 | 10 | V | |

Input R_S, C_S

(refer to calculation formulae)

| | | | | | | |
|-------------------|-------|----|--|-----|------------|--|
| Limit value C_S | C_S | 5 | | 100 | nF | |
| Limit value R_S | R_S | 33 | | | k Ω | |

Dimensioning notes and calculation formulae

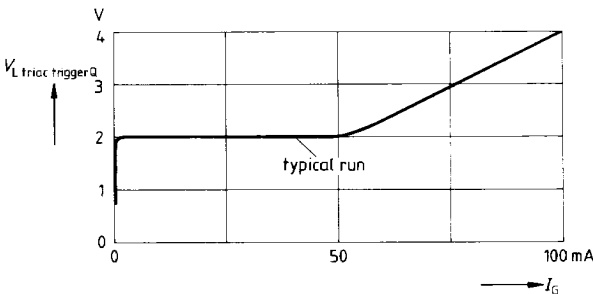
1. Select trigger pulse width according to triac type and load.
2. **Calculate** C_S (for a $V_{control}$ domination)
 C_S (nF) = trigger pulse width (μs) \times 0.2
 The formula yields the typical value
 e.g. $T = 50 \mu s$ results in $C_S = 10$ nF
3. **Calculate** R_S (for 4 V max. sawtooth voltage)

$$R_S \text{ (k}\Omega\text{)} = \frac{1}{\text{trigger pulse width } (\mu s)} \times 2 \times 10^4$$

The formula yields the typical value
 e.g. $T = 50 \mu s$ results in $R_S = 400$ k Ω

4. **Select** R_{SYNC} **resistance at SYNC input**
 The sync pulse width (from $V_S \pm 7.5$ V, $I_{SYNC} = \pm 20 \mu A$) has to be twice as large as the trigger pulse width.
- 4.1 Sync pulse width $\geq 2 \times$ trigger pulse width \times safety factor (according to component deviation and line voltage variation).
- 4.2 R_{SYNC} (k Ω) = [sync pulse width (μs) \times line voltage (V rms) \times $2.23 \times 10^{-4} - 7.5$] \times 50
 e.g. $560 \mu s$ sync pulse width and 220 V rms result in $R_{SYNC} = 1$ M Ω .
 With 220 V rms line voltage, the minimum permissible resistance R_{SYNC} is 100 k Ω corresponding to a pulse width of 195 μs .
5. **Calculate** R_G

$$R_G = \frac{V_S - \text{triac gate voltage} - \text{low-voltage triac trigger output}}{I_G}$$



6. **Calculate** R_S

6.1 Calculation of R_S requires first of all the determination of the total current consumption. Insert the arithmetic mean values of the currents for one line cycle.

6.2 $\bar{I}_{\text{tot}} = \bar{I}_S = 3.2 \text{ mA} + \bar{I}(V_{\text{ref}}) + \bar{I}_{Q1} \text{ (OP)} + \bar{I}_{Q2} \text{ (K3)} + \bar{I} \text{ (driver output)} + \bar{I} \text{ (additional external circuit currents)} + I \bar{I} (R_{\text{SYNC}})$.

6.3 $R_S \text{ (k}\Omega) = \frac{\text{rms line voltage (V)}}{\bar{I}_{\text{tot}} \text{ (mA)}} \times 0.455 \times \text{safety factor}$

(corresponding to component deviation and line voltage variation)

e.g. $\bar{I}_{\text{tot}} = 5 \text{ mA}$ und $V_{\text{line}} = 220 \text{ V}$ result in $R_S = 20 \text{ k}\Omega$.

Employing the internal Z diode reduces the IC's V_S voltage to 14.5 V.

7. **Calculate** C_G

7.1 Selection of the maximum permissible ripple at the V_S input, based on the desired functional quality and the special external components.

7.2 The ripple amplitude at the V_S input of the unit should not exceed $V_{pp} = 2 \text{ V}$.

7.3 $C_G \text{ (}\mu\text{F)} \geq \frac{\bar{I}_{\text{tot}} \text{ (mA)}}{V_{pp}} \times 15$

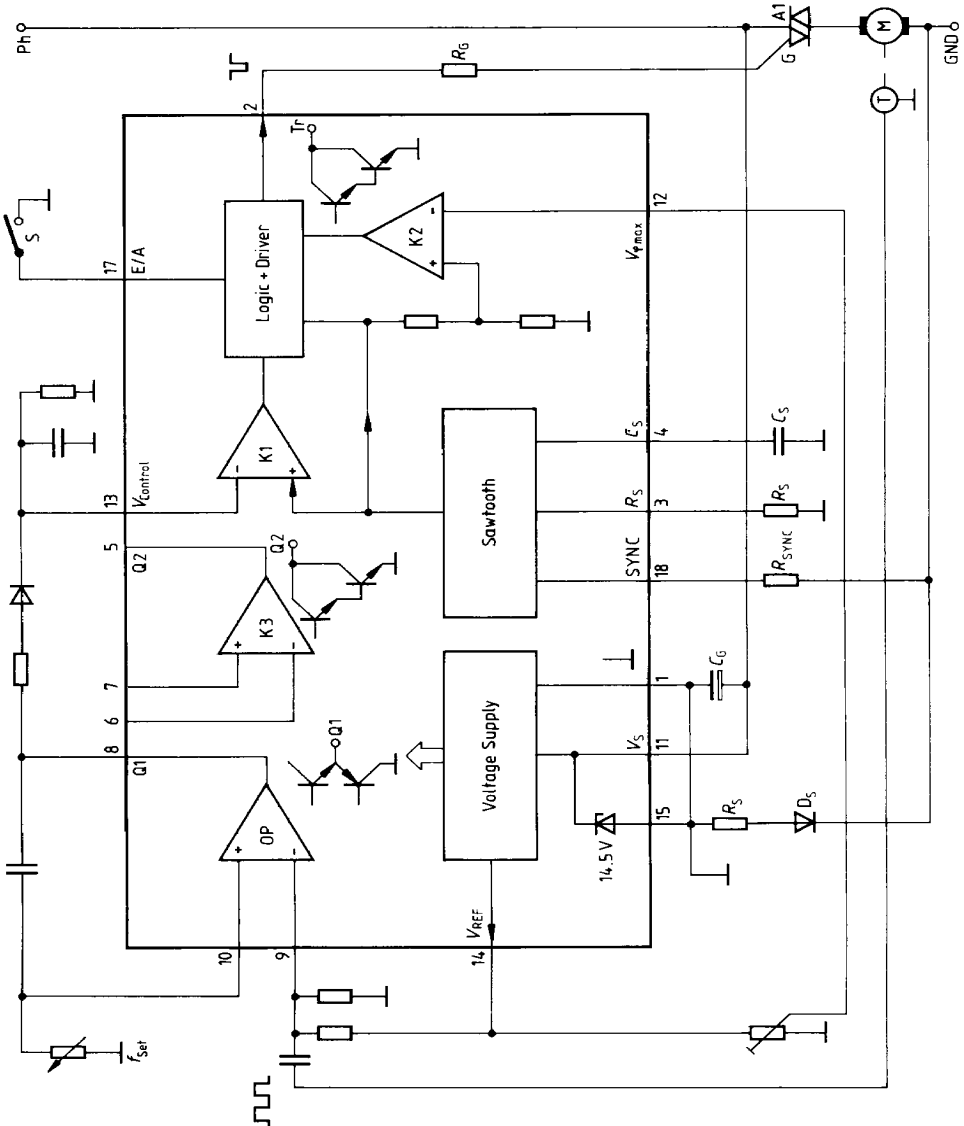
e.g. ripple $V_{pp} = 0.75 \text{ V}$; $\bar{I}_{\text{tot}} = 5 \text{ mA}$ results in $C_G = 100 \mu\text{F}$

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Application Examples

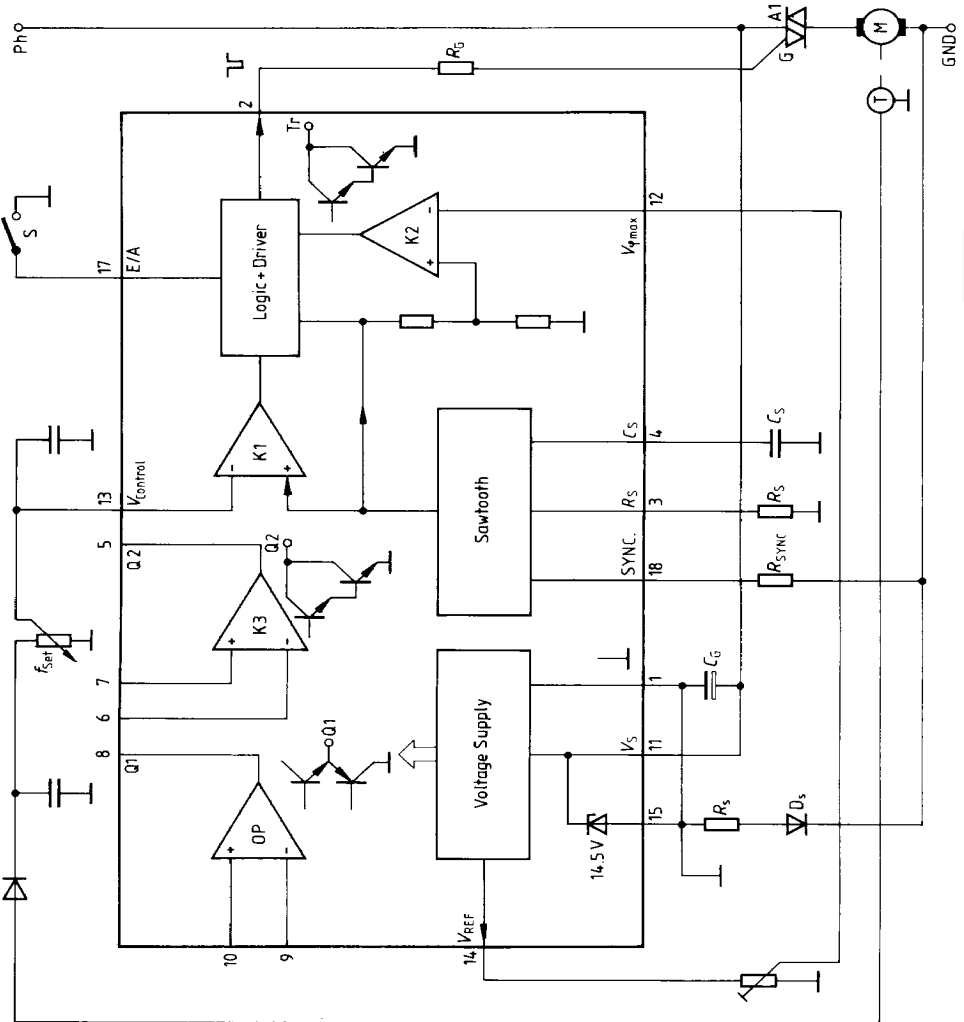
Schematic Circuit Diagram for Motor Control Using TLE 3101

The tachogenerator provides a **frequency** processed by the op amp (monoflop).



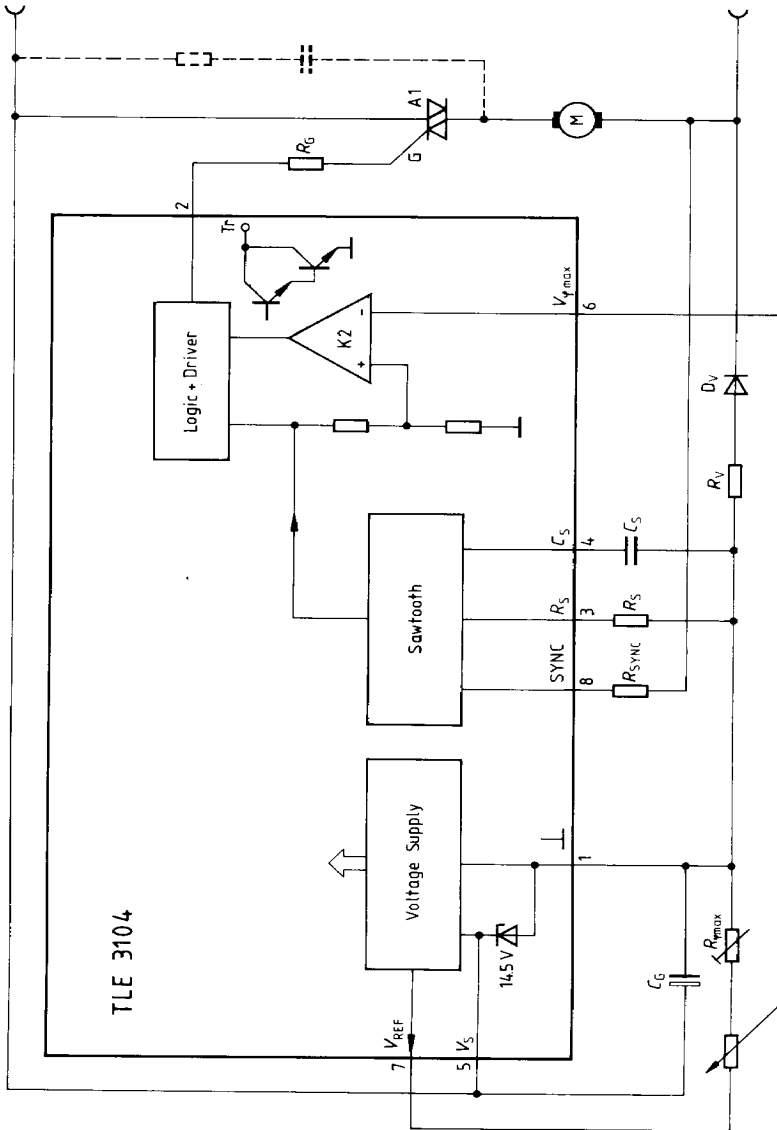
Schematic Circuit Diagram for Motor Control Using TLE 3101

The tachogenerator provides a **voltage** which is rectified and stabilized, and then fed into input $V_{Control}$.



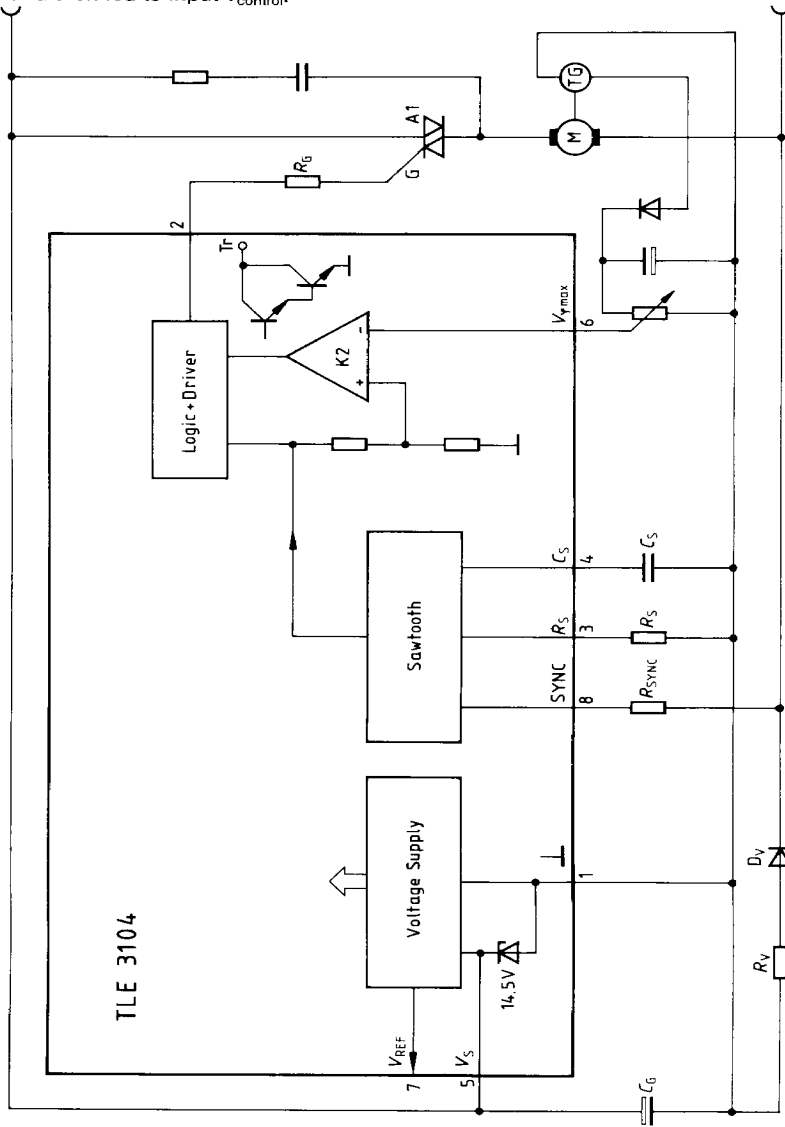
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Schematic Circuit Diagram for Motor Control Using TLE 3104



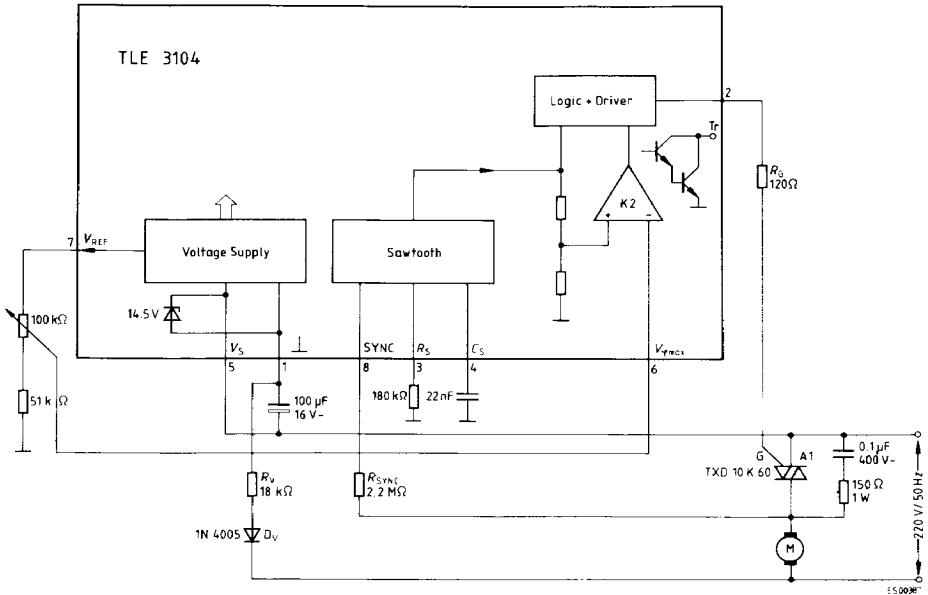
Schematic Circuit Diagram for Motor Control Using TLE 3104

The tachogenerator supplies a **voltage**, which is rectified and stabilized and then fed to input $V_{Control}$.



Current Synchronization in Case of Inductive Load Control Using TLE 3104

Particularly in case of phase control of inductive loads, such as transformers and shaded-pole motors, there is a risk of half-wave operation as a result of the phase shift between voltage and current. In order to avoid this condition, the synchronization resistor is connected to A 2 of the triac (this method cannot be applied in the event of severe brush sparking of the motor).



Notes

The pulse width selected for the trigger pulse must be so great that the triac reaches its holding current, even with a great phase angle (critical: positive half-wave). For this reason, it may be necessary to select a lower value for the ac line series resistor.

The sync pulse must be at least twice as wide as the trigger pulse.