642 010/022

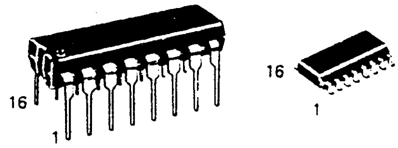
MOTOROLA
SEMICONDUCTOR
TECHNICAL DATA

TDA1085C

642-010/022

UNIVERSAL MOTOR SPEED CONTROLLER

LINEAR INTEGRATED CIRCUIT



PLASTIC PACKAGE
CASE 648

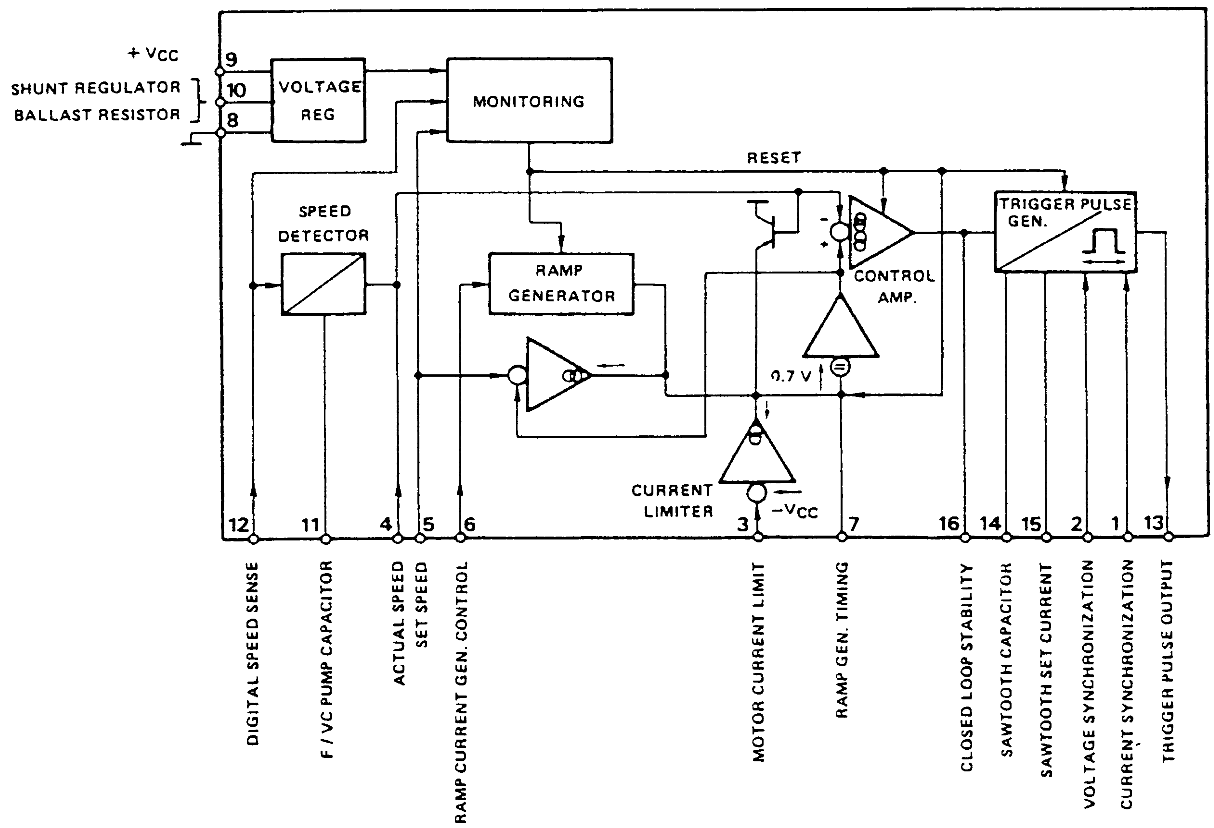
D SUFFIX
PLASTIC PACKAGE
CASE 751B
(SO-16)

UNIVERSAL MOTOR SPEED CONTROLLER

The TDA1085C is a phase angle triac controller having all the necessary functions for universal motor speed control in washing machines. It operates in closed loop configuration and provides two ramps possibilities.

- On-Chip Frequency to Voltage Converter
- On-Chip Ramps Generator
- Soft Start
- Load Current Limitation
- Tachogenerator Circuit Sensing
- Direct Supply from AC Line
- Security Functions Performed by Monitor

FIGURE 1 — BLOCK DIAGRAM AND PIN ASSIGNMENT



MAXIMUM RATINGS (T_A = 25°C, Voltages are referred to pin 8, Ground)

Rating	Symbol	Value	Unit
Power Supply, when externally regulated, V_{Pin9}	V_{CC}	15	V
Maximum Voltage per listed pin Pin 3 Pin 4-5-6-7-13-14-16 Pin 10	V_{pin}	 +5.0 0 to $+V_{CC}$ 0 to +17	V
Maximum Current per listed pin Pin 1 and 2 Pin 3 Pin 9 (V_{CC}) Pin 10 shunt regulator Pin 12 Pin 13	I_{pin}	 −3.0 to +3.0 −1.0 to +0 15 35 −1.0 to +1.0 −200	mA
Maximum Power Dissipation	P_D	1.0	W
Junction to Air Thermal Resistance	$R_{\theta JA}$	65	°C/W
Operating Junction Temperature	T_A	−10 to +120	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C)

Characteristic	Symbol	Min	Typ	Max	Unit
VOLTAGE REGULATOR					
Internally Regulated Voltage (V_{Pin9}) (I_{Pin7} = 0, I_{Pin9} + I_{Pin10} = 15 mA, I_{Pin13} = 0)	V_{CC}	15	15.3	15.6	V
V_{CC} Temperature Factor	TF	—	−100	—	ppm/°C
Current Consumption (I_{Pin9}) (V_9 = 15 V, V_{12} = V_8 = 0, I_1 = I_2 = 100 µA, all other pins not connected)	I_{CC}	—	4.5	6.0	mA
V_{CC} Monitoring Enabling Level Disable Level	V_{CC} EN V_{CC} DIS	— —	$V_{CC}-0.4$ $V_{CC}-1.0$	— —	V
RAMP GENERATOR					
Reference Speed Input Voltage Range	V_{Pin5}	0.08	—	13.5	V
Reference Input Bias Current	$-I_{Pin5}$	0	0.8	1.0	µA
Ramp Selection Input Bias Current	$-I_{Pin6}$	0	—	1.0	µA
Distribution Starting Level Range	V_{DS}	0	—	2.0	V
Distribution Final Level V_{Pin6} = 0.75 V	V_{DF}/V_{DS}	2.0	2.09	2.2	
High Acceleration Charging Current V_{Pin7} = 0 V V_{Pin7} = 10 V	$-I_{Pin7}$	 1.0 1.0	 — 1.2	 1.7 1.4	mA
Distribution Charging Current V_{Pin7} = 2.0 Volts	$-I_{Pin7}$	4.0	5.0	6.0	µA

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
CURRENT LIMITER					
Limiter Current Gain — I_{Pin7}/I_{Pin3} (I_{Pin3} = −300 μA)	C_g	130	180	250	
Detection Threshold Voltage I_{Pin3} = −10 μA	$V_{Pin3\ TH}$	50	65	80	mV
FREQUENCY TO VOLTAGE CONVERTER					
Input Signal "Low Voltage"	$V_{12\ L}$	−100	—	—	mV
Input Signal "High Voltage"	$V_{12\ H}$	+100	—	—	mV
Monitoring Reset Voltage	$V_{12\ R}$	5.0	—	—	V
Negative Clamping Voltage I_{Pin12} = −200 μA	$-V_{12\ CL}$	—	0.6	—	V
Input Bias Current	$-I_{Pin12}$	—	25	—	μA
Internal Current Source Gain $G = \frac{I_{Pin4}}{I_{Pin11}}$, $V_{Pin4} = V_{Pin11} = 0$	G.0	9.5	—	11	
Gain Linearity versus Voltage on Pin 4 ($G_{8.6}$ = Gain for V_{Pin4} = 8.6 Volts)	$G/G_{8.6}$				
V_4 = 0 V		1.04	1.05	1.06	
V_4 = 4.3 V		1.015	1.025	1.035	
V_4 = 12 V		0.965	0.975	0.985	
Gain Temperature Effect (V_{Pin4} = 0)	TF	—	350	—	ppm/°C
Output Leakage Current (I_{Pin11} = 0)	$-I_{Pin4}$	0	—	100	nA
CONTROL AMPLIFIER					
Actual Speed Input Voltage Range	V_{Pin4}	0	—	13.5	V
Input Offset Voltage $V_{Pin5} - V_{Pin4}$ (I_{Pin16} = 0, V_{Pin16} = 3.0 and 8.0 Volts)	V_{off}	0	—	50	mV
Amplifier Transconductance ($I_{Pin16}/\Delta(V_5 - V_4)$) ($I_{Pin16}$ = + and −50 μA, V_{Pin16} = 3.0 Volts)	T	270	340	400	μA/V
Output Current Swing Capability	I_{Pin16}				μA
Source		−200	−100	−50	
Sink		50	100	200	
Output Saturation Voltage	$V_{16\ sat}$	—	—	0.8	V
TRIGGER PULSE GENERATOR					
Synchronization Level Currents					μA
Voltage Line Sensing	I_{Pin2}	—	±50	±100	
Triac Sensing	I_{Pin1}	—	±50	±100	
Trigger Pulse Duration (C_{Pin14} = 47 nF, R_{Pin15} = 270 kΩ)	T_p	—	55	—	μs
Trigger Pulse Repetition Period, conditions as a.m.	T_R	—	220	—	μs
Output Pulse Current $V_{Pin13} = V_{CC}$ −4.0 Volts	$-I_{Pin13}$	180	192	—	mA
Output Leakage Current V_{Pin13} = −3.0 Volts	$I_{13\ L}$	—	—	30	μA
Full Angle Conduction Input Voltage	V_{14}	—	11.7	—	V
Saw Tooth "High" Level Voltage	$V_{14\ H}$	12	—	12.7	V
Saw Tooth Discharge Current, I_{Pin15} = 100 μA	I_{Pin14}	95	—	105	μA

TRIGGER PULSE GENERATOR — (pins 5 1-2-13-14-15)
This circuit performs four functions:

- The conversion of the control amplifier DC output level to a proportionnal firing angle at every main line half cycle.
- The calibration of pulse duration.
- The repetition of the pulse if the triac fails to latch on if the current has been interrupted by brush bounce.
- The delay of firing pulse until the current crosses zero at wide firing angles and inductive loads.

$R_{pin\,15}$ programs the pin 14 discharging current. Saw-tooth signal is then fully determined by R15 and C14 (usually 47 nF). Firing pulse duration and repetition period are in inverse ratio to the saw-tooth slope.

Pin 13 is the pulse output and an external limiting resistor is mandatory. Max current capability is 200 mA.

CURRENT LIMITER — (pin 3) Safe operation of the motor and triac under all conditions is ensured by limiting the peak current. The motor current develops an alternative voltage in the shunt resistor (0.05 ohm in fig. 4). The negative half waves are transferred to pin 3 which is positively preset at a voltage determined by resistors R_3 and R_4. As motor current increases, the dynamical voltage range of pin 3 increases and when pin 3 becomes slightly negative in respect of pin 8 a current starts to circulate in it. This current, amplified typically 180 times, is then used to discharge pin 7 capacitor and, as a result, reduces firing angle down to a value where an equilibrium is reached. The choice of resistors R_3, R_4 and shunt determines the magnitude of the discharge current signals on C_{pin7}.

Notice that the current limiter acts only on peak Triac current.

APPLICATION NOTES
(Referred to Figure 4)

PRINTED CIRCUIT LAYOUT RULES
In the common applications, where TDA1085C is used, there is on the same board, presence of high voltage, high currents as well as low voltage signals where millivolts count. It is of first magnitude importance to separate them each other and to respect following rules:

- Capacitors decoupling pins which are the inputs of the same comparator, must be physically close to the IC, close to each other and grounded in the same point.
- Ground connexion for tachogenerator must be directly connected to pin 8 and should ground only the tacho. In effect the latter is a first magnitude noise generator due to its proximity of the motor which induces high dØ/dt signals.
- The ground pattern must be in the "star style", in order to fully eliminate power currents flowing in the ground network devoted to capacitors decoupling sensitive pins: (4-5-7-11-12-14-16).

As an example, fig. 5 presents a PC board pattern which concerns the group of sensitive pins and their associated capacitors into which the a.m. rules have been implemented. Notice the full separation of "Signal World" from "Power" one by line AB and their communication by a unique strip.

These rules will lead to much satisfactory volume production in the sense that speed adjustment will stay valid in the entire speed range.

POWER SUPPPLY
As dropping resistor dissipates noticeable power, it is necessary to reduce the I_{CC} needs down to a minimum. Triggering pulses, if a certain number of repetition is in reserve to cope with motor brush wearing at end of its life, are the largest I_{CC} user. Classical worst case configuration have to be considered to select dropping resistor. In addition the parallel regulator must be always into its dynamic range, i.e. $I_{pin\,10}$ over 1 mA and $V_{pin\,10}$ over 3 volt in any extreme configuraton. The double filtering cell is mandatory.

TACHOGENERATOR CIRCUIT
The tacho signal voltage is proportional to the motor speed. Stability considerations, in addition, require a RC filter the pole of which must be looked at. The combination of both elements yield a constant amplitude signal on pin 12 in most of the speed range. It is recommended to verify this maximum amplitude to be within 1 volt peak in order to have the largest signal/noise ratio without resetting the integrated circuit (which occurs if $V_{pin\,12}$ reaches 5.5 V). It must be also verified that the pin 12 signal is approximately balanced between "High" (over 300 mV) and "Low". A 8 poles tacho is a minimum for low speed stability and a 16 poles is even better.

The RC pole of the tacho circuit should be chosen within 30 Hz in order to be as far as possible from the 150 Hz which corresponds to the AC line 3rd harmonic generated by the motor during starting procedure. In addition, a high value resistor coming from V_{CC} introduces a positive offset at pin 12, removes noise to be interpreted as a tacho signal. This offset should be designed in order to let pin 12 to reach at least − 200 mV (negative voltage) at the lowest motor speed. We remember the necessity of an individual tacho ground connection.

FREQUENCY TO VOLTAGE CONVERTER — F V/C
C_{pin} 11jhas a recommended value of 820 pF for 8 poles tachos and max. motor rpm of 15000, and R_{Pin} 11 must be always 470 K.
R_{Pin} 4 should be choosen to deliver within 12 volts at maximum motor speed in order to maximize signal/noise ratio. As the FV/C ratio as well as the C_{pin} 11 value are dispersed, R_{Pin} 4 must be adjustable and should be made of a fixed resistor in serice with a trimmer representing 25% of the total. Adjustment would become easier.
Once adjusted, for instance at maximum motor speed, the F V/C presents a residual non linearity; the conversion factor (mV per R.P.M.) increases by within 7.7% as speed tends to zero. The guaranteed dispersion of the latter being very narrow, a maximum 1% speed error is guaranteed if during pin 5 network design the small set vlues are modified, once for ever, according this increase.

The following formulae give V_{pin} 4:

$$V_{Pin\,4} = G.0 \cdot (V_{CC} - V_a) \cdot C_{Pin\,11} \cdot R_4 \cdot f \cdot \frac{1}{\left(1 + \frac{120k}{R_{Pin11}}\right)}$$

In Volts ·
$G.0 \cdot (V_{CC} - V_a) \simeq 140$
$V_a = 2.0\,V_{BE}$
$120k = R_{int}$, on Pin 11

SPEED SET — (pin 5) Upon designer choice, a set of external resistors apply a serie of various voltages corresponding to the various motor speeds. When switching external resistors, verify that a voltage below 80 mV in never applied to pin 5, if no, a full circuit reset will occur.

RAMPS GENERATOR — (pin 6) If only a high acceleration ramp is needed, connect pin 6 to ground.

When a Distribute ramp should occur, pre-set a voltage on pin 6 to which corresponds the motor speed starting ramp point. Distribution (or low ramp) will continue up to the moment the motor speed would have reached twice the starting value.

The ratio of two is imposed by the IC. Nevertheless it could be externally changed downwards (fig. 6) or upwards (fig. 7).

The distribution ramp can be shortened by an external resistor from V_{CC} charging $C_{pin\ 7}$, adding its current to the internal 5 µA generator.

POWER CIRCUITS

Triac Triggering pulse amplitude must be determined by Pin 13 resistor according the needs in Quadrant IV. Trigger pulses duration can be disturbed by noise signals, generated by the triac itself, which interfere within pins 14 and 16, precisely those which determine it. While easily visible this effect is harmless.

Triac must be protected from high AC line dV/dt during external disturbances by 100 nF × 100 Ω network.

Shunt resistor must be as non selfic as possible. It can be made locally by Constantan alloy wiring.

When the load is a DC fed universal motor through a rectifier bridge, the triac must be protected from commutating dV/dt by a 1 to 2 mH coil in serie with MT_2.

Synchronisation functions are performed by resistors sensing AC line and triac conduction. 820 K values are usual but could be reduced down to 330 K in order to detect the Zeros with accuracy and to reduce the residual DC line component below 20 mA.

CURRENT LIMITATION

The current limiter starts to discharge pin 7 capacitor (reference speed) as Motor current reaches the designed threshold level. The loop gain is determined by the resistor connecting pin 3 to the serie shunt. Experience has shown that its optimal value for a 10 A rms limitation is within 2 KΩ. Pin 3 input has a sensitivity in current which is limited to reasonable values and should not react to spikes.

If not used, pin 3 must be connected to a max. positive voltage of 5 V rather to be left open.

LOOP STABILITY

The pin 16 network is predominant and must be adjusted experimentally during module development. The values indicated in fig. 4 are typical for washing machines applications but accept large modifications from one model to another. R16, it is the sole restriction, should not be below 33 k otherwise slew rate limitation will cause large transient errors for load steps.

FIGURE 2 — ACCELERATION RAMP

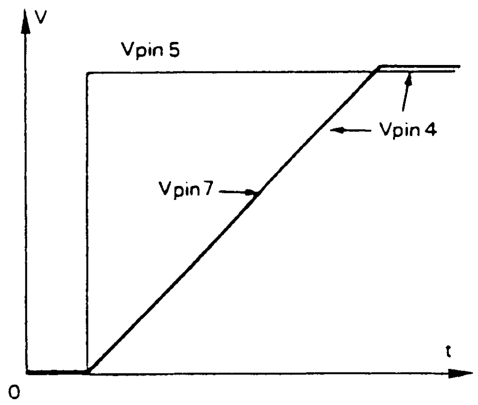


FIGURE 3 — PROGRAMMABLE DOUBLE ACCELERATION RAMP

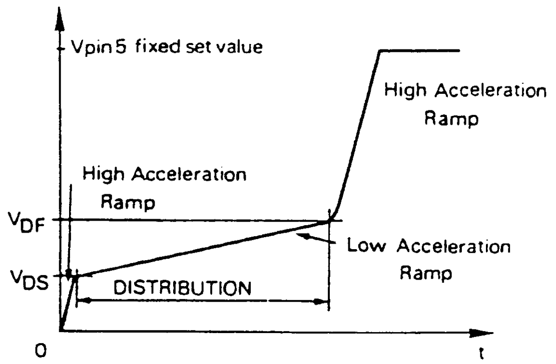
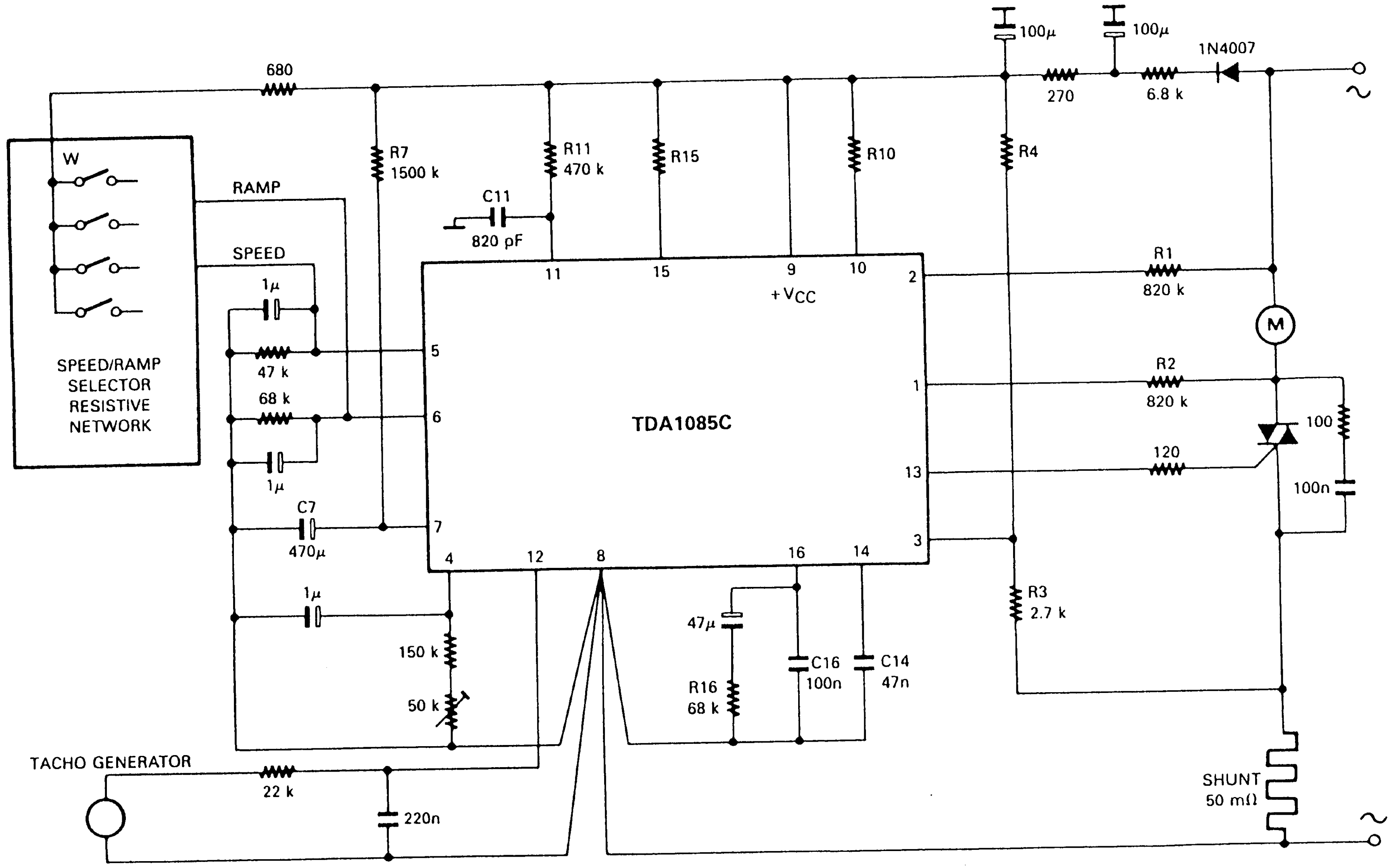


FIGURE 4 — BASIC APPLICATION CIRCUIT



Current limitation: 10 A adjusted by R_4 experimentally

Ramps High acceleration: 3200 rpm per second

Distribution ramp: 10 s from 850 to 1300 rpm

Speeds:	**Pin 5 voltage Set:**	
Wash 800 rpm	609 mV	Including nonlinearity corrections
Distribution 1300	996 mV	Including nonlinearity corrections
Spin 1: 7500	5,912 V	Including nonlinearity corrections
Spin 2: 15,000	12,000 V	Adjustment point

Motor Speed Range: 0 to 15,000 rpm

Tachogenerator 8 poles
delivering 30 V peak to peak at 6000 rpm, in open circuit

FV/C Factor: 8 mV per rpm (12 V full speed) C_{pin11} = 680 pF V_{CC} = 15.3 V

TRIAC MAC15A-8 15 A 600 V

Igt min = 90 mA to cover Quad IV at − 10°C

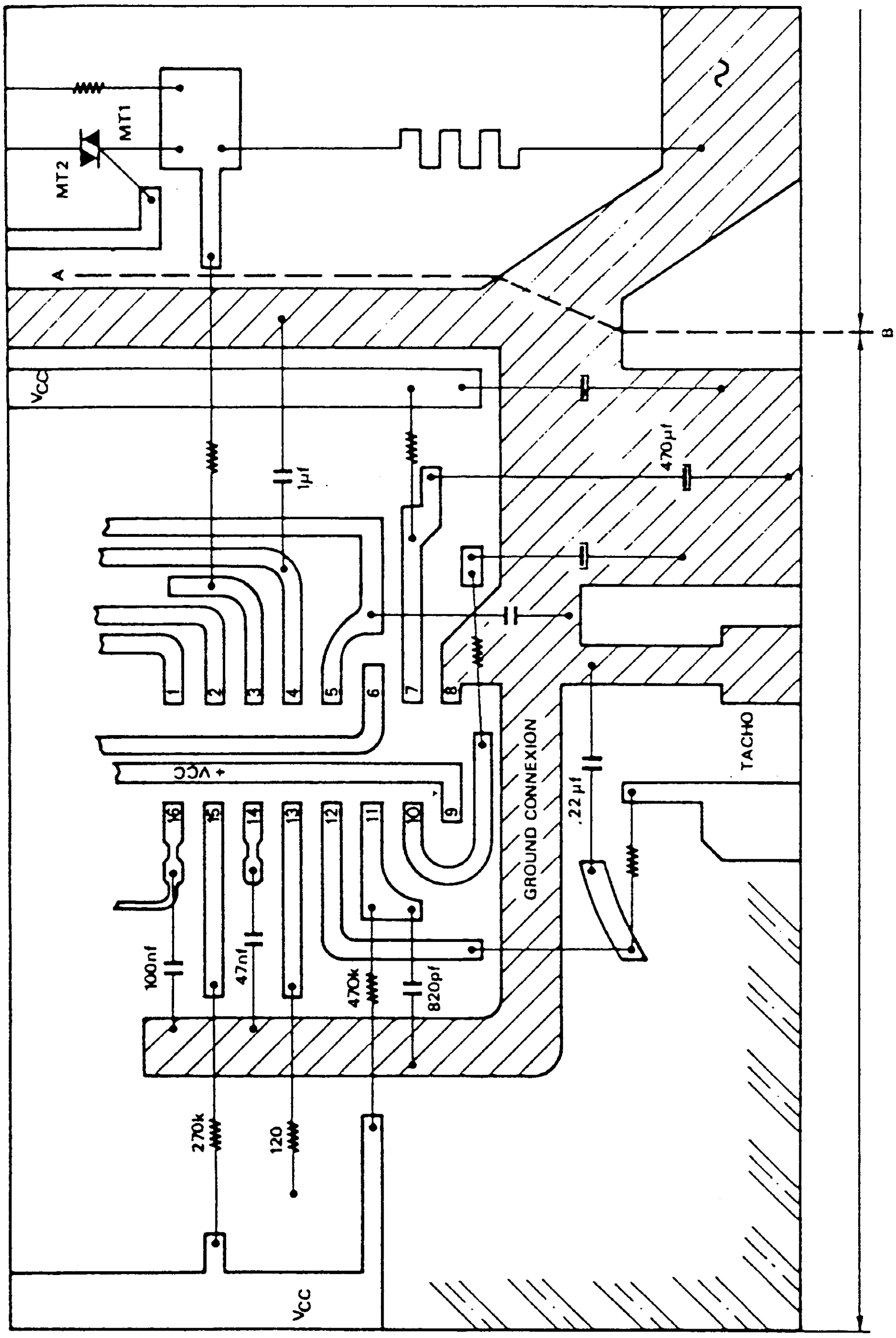


FIGURE 5 — PC BOARD LAYOUT

FIGURE 6 — DISTRIBUTION SPEED k < 2

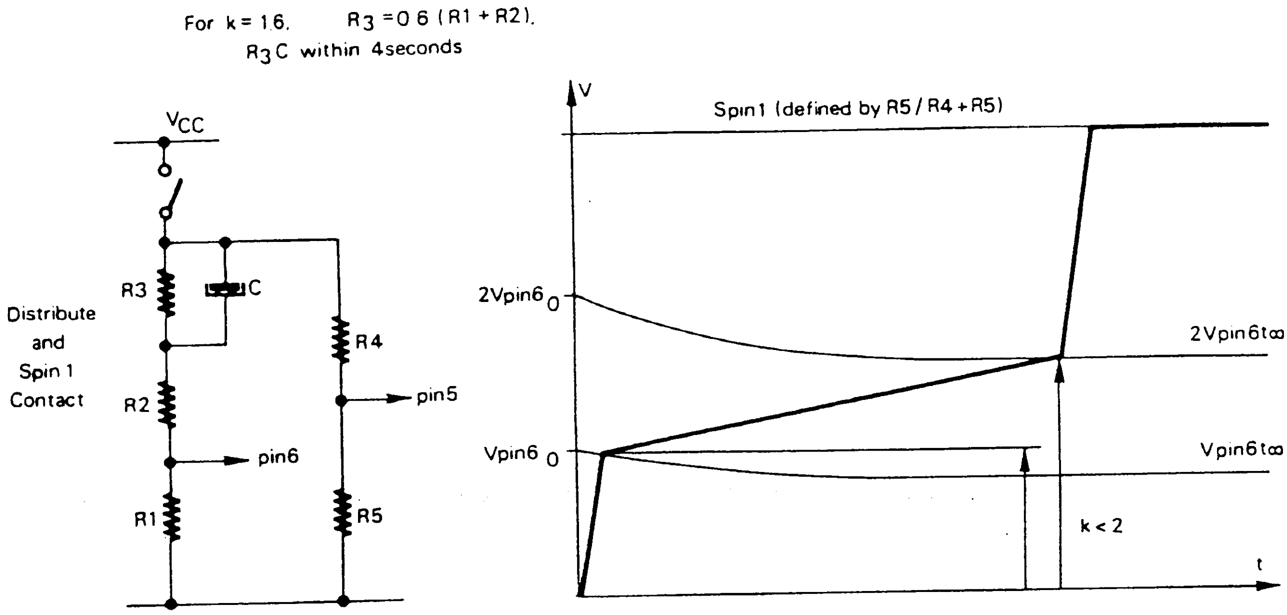


FIGURE 7 — DISTRIBUTON SPEED k > 2

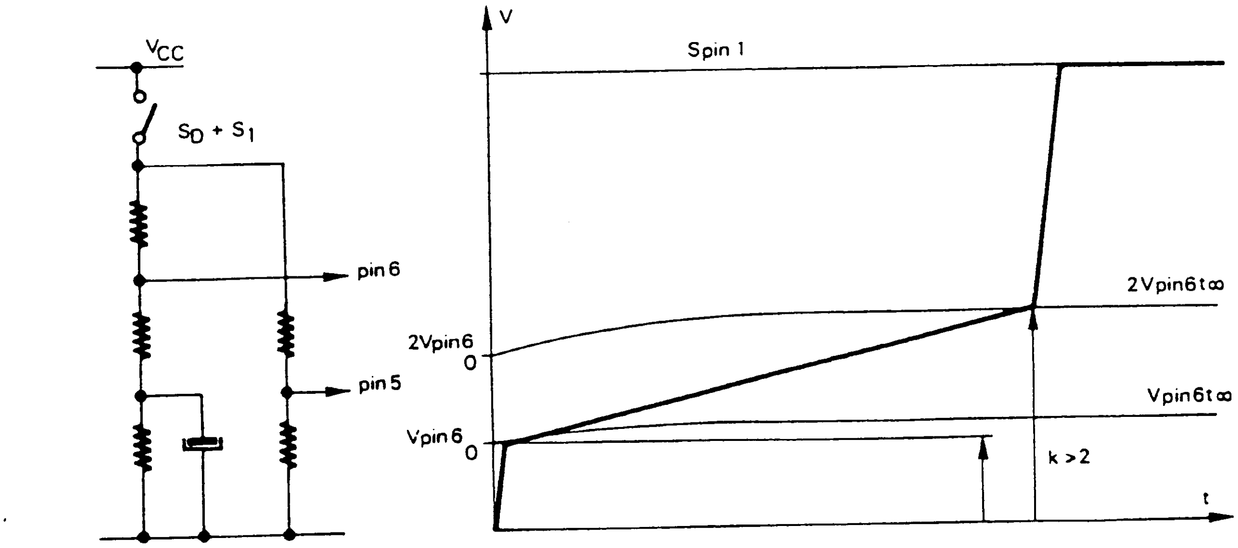


FIGURE 8 — SIMPLIFIED SCHEMATIC