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## TEA5170 - SECONDARY CONTROLLER FOR MASTER-SLAVE STRUCTURE

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# TEA5170 - SECONDARY CONTROLLER FOR MASTER-SLAVE STRUCTURE

## I - INTRODUCTION

The TEA 5170 is designed to work in the secondary part of SMPS, sending pulses to the slave TEA2164 which is located on the primary side of the main transformer.

The function of the regulation and synchronization are carried out by the TEA5170.

An accurate regulated voltage is obtained by duty cycle control.

The TEA5170 can be externally synchronized by a frequency higher or lower than the free-running frequency. This feature is particularly suitable for TV applications.

## II - OPERATING PRINCIPLES OF MASTER-SLAVE STRUCTURE

This architecture offers two modes of operation :

- Master-slave mode (for normal operation)
- Burst mode (used during start-up and stand-by phases)

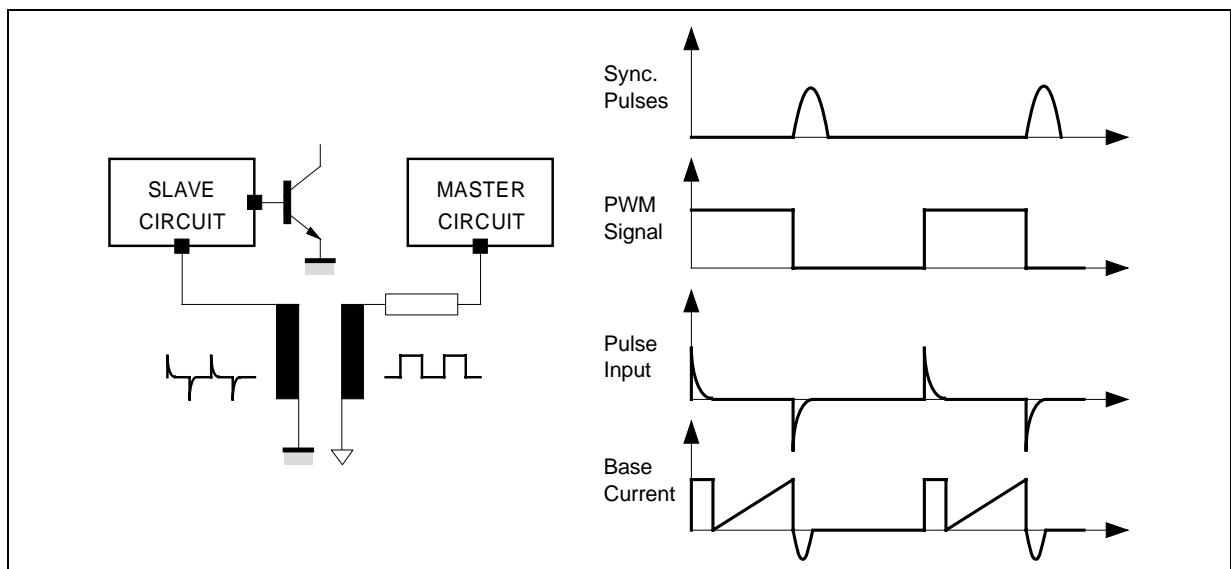
### II.1 - Master-Slave Mode

In this configuration, the master circuit located on the primary side, issues PWM pulses used for output voltage regulation. These pulses are sent via a pulse transformer to the slave circuit (Figure 1). In this mode of operation, the falling edge of PWM signal may be synchronized by an external signal (e.g. by line flyback signal in TV applications).

### II.2 - Burst Mode

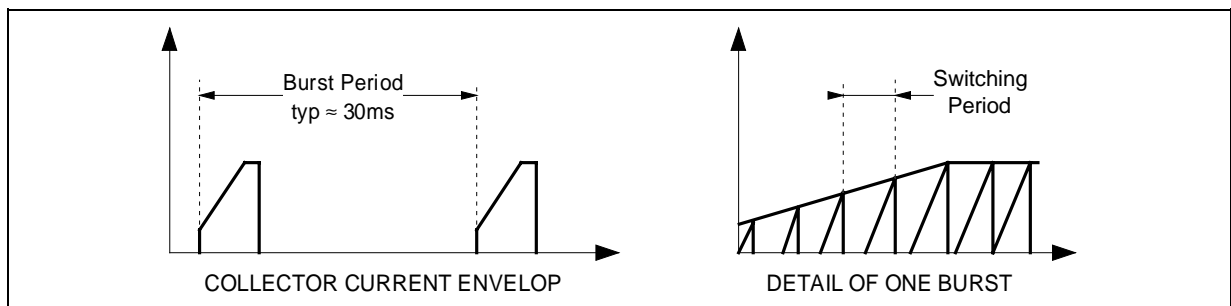
During start-up and stand-by phases, no regulation pulses are issued by the master circuit and thus the slave circuit operates in burst mode. In this configuration, the slave circuit determines the switching frequency and the burst period (see Figure 2).

Figure 1



5170-12.EPS

Figure 1



5170-13.EPS

## TEA5170 - SECONDARY CONTROLLER FOR MASTER-SLAVE STRUCTURE

### II.3 - Operation of a Master-Slave Supply in TV Application

The arrangement generally employed is depicted in Figure 3. On the secondary side, a microcontroller is connected to the remote control receiver which issues control signals for stand-by and normal modes of operation (Figure 4).

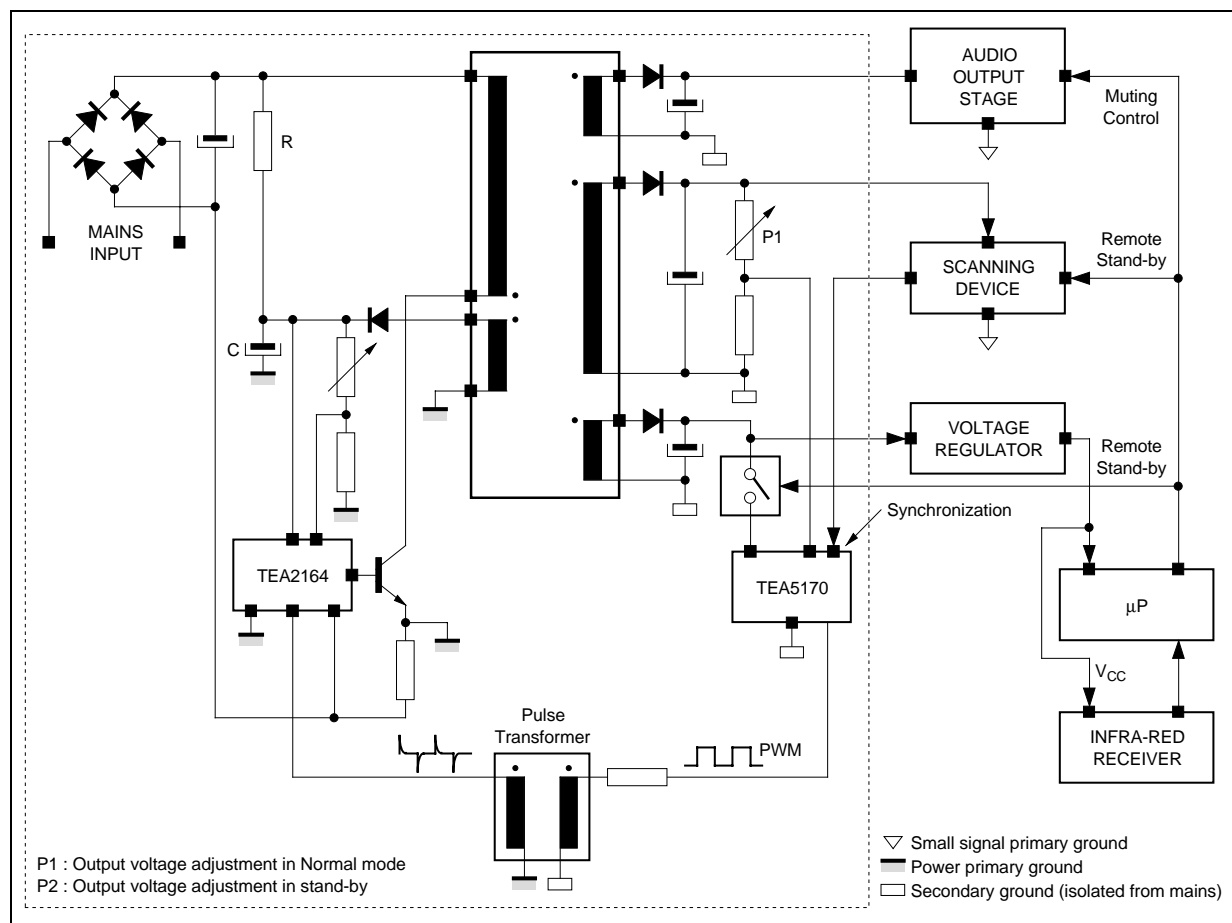
- In stand-by mode, the device power consumption is low (few Watts). The master will no longer send any control pulses to the slave which will consequently begin operating in burst mode.
- Power supply regulation is performed by the slave circuit through the auxiliary winding.

- In normal mode of operation, the master circuit issues the PWM signal for regulation. The power supply operates in master-slave mode. The master circuit is simultaneously synchronized with the line flyback signal.

- Power supply start-up. As soon as the  $V_{CC}$  (START) threshold is reached, the slave circuit begins operating in burst mode. While the secondary voltages are being stabilized, the microcontroller holds the TV set in stand-by mode.

Once the start-up phase is terminated, the set may remain in stand-by mode or switch into normal mode of operation.

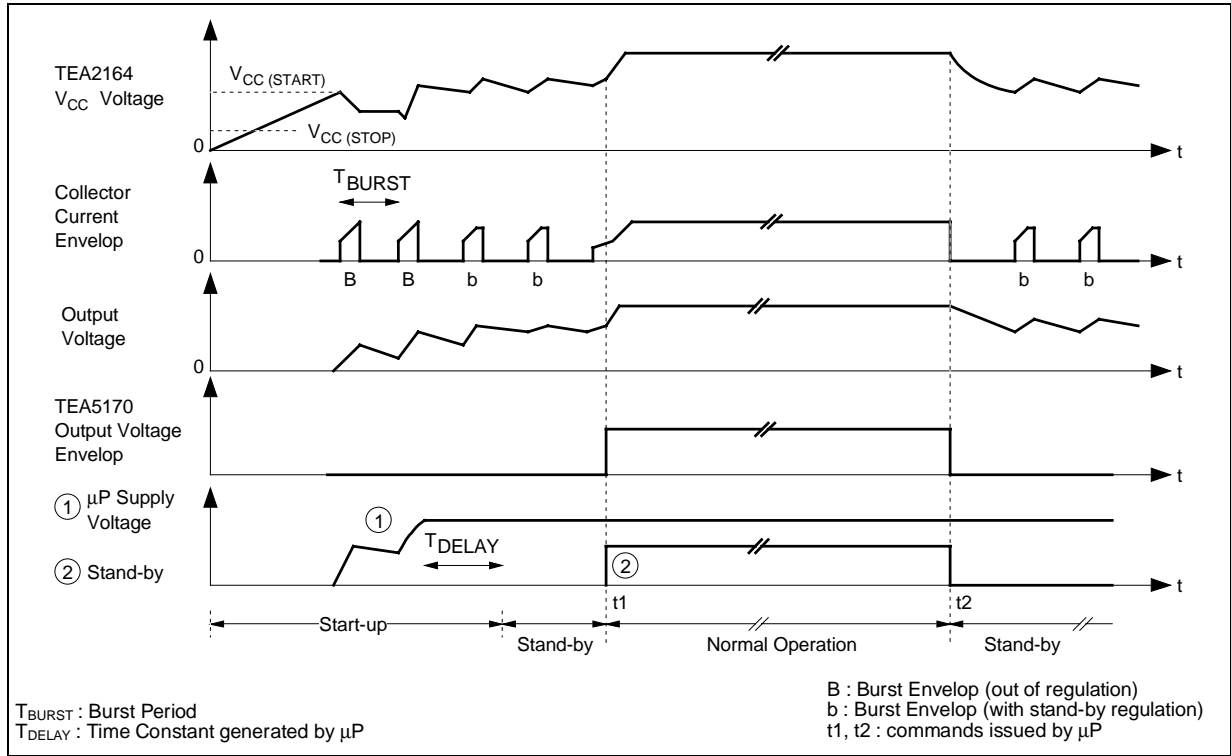
Figure 3



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Figure 4



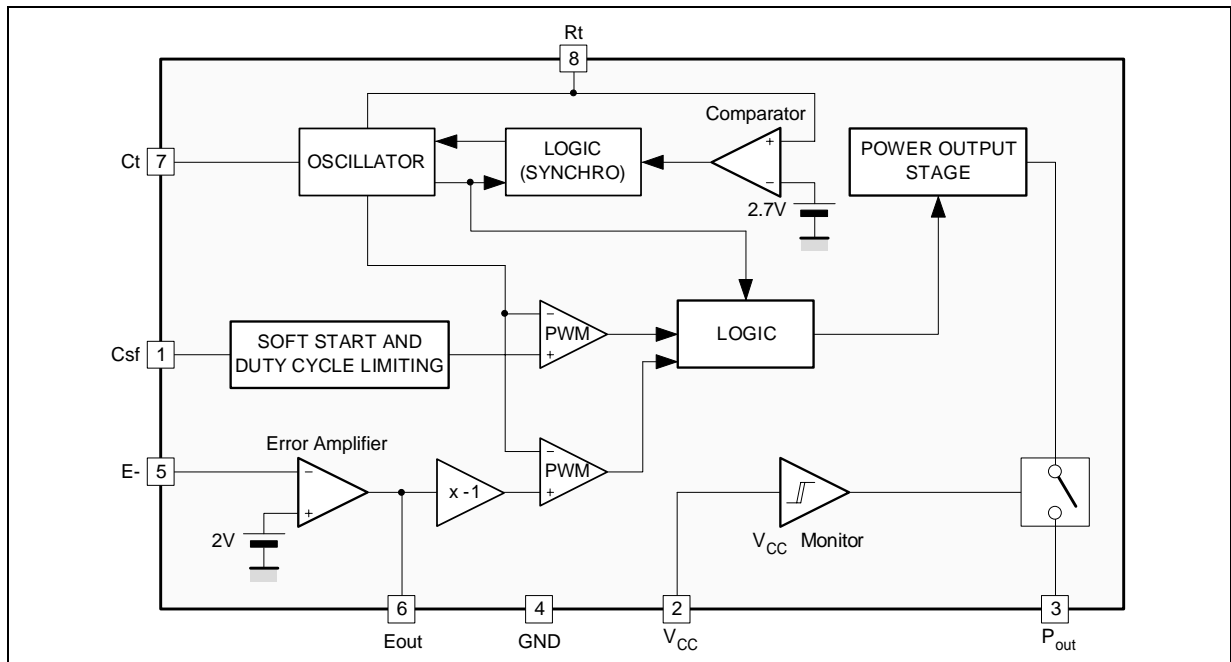
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## III - DESCRIPTION OF TEA 5170

The TEA5170 is a fixed frequency PWM signal generator operating in voltage mode regulation.

### III.1 - Block Diagram

Figure 5 : Block Diagram



5170-02.EPS

**III.2 - Oscillator**

The oscillator generates a linear saw-tooth signal and sets the free-running frequency. This oscillator can also operate in synchronized mode.

**III.2.1 - Operation in free-running frequency mode** (See Figure 6)

**III.2.2 - Operation in synchronized mode**

The oscillator is synchronized by forcing the saw-tooth return.

*Enabling the synchronized mode (Figure 7)*

The synchronized mode is enabled when the signal pulse on Pin 8 (R<sub>t</sub>) coincides with the oscillator saw-tooth return. The "C<sub>t</sub>" capacitor charge current is then multiplied by a factor of 0.75.

The TEA5170 will remain in synchronized mode as

long as the synchronization pulses fall within the following window :

$$(0.8 T_1 + T_2) < T_{\text{SYNC}} < (1.33 T_1 + T_2)$$

Where :

- T<sub>1</sub> : C<sub>t</sub> charge time in non synchronized mode.
- T<sub>2</sub> : C<sub>t</sub> discharge time

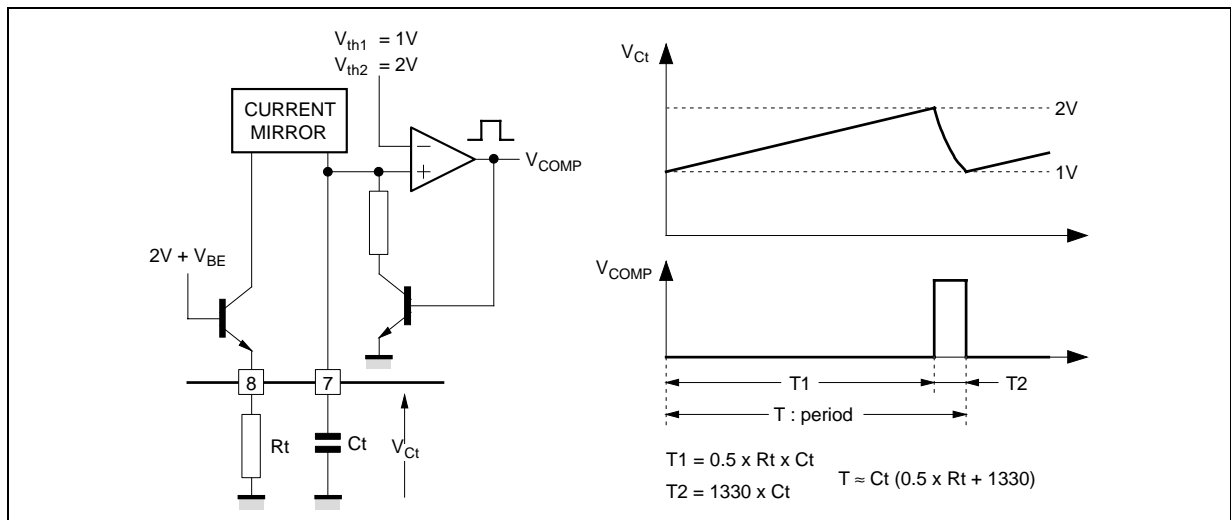
*Synchronization signal (Figure 8)*

Synchronization signal is applied to Pin 8 "R<sub>t</sub>" and the capacitor "C<sub>t</sub>" is discharged when voltage "V<sub>Rt</sub>" exceeds the "2.7 V" threshold.

**Comment :**

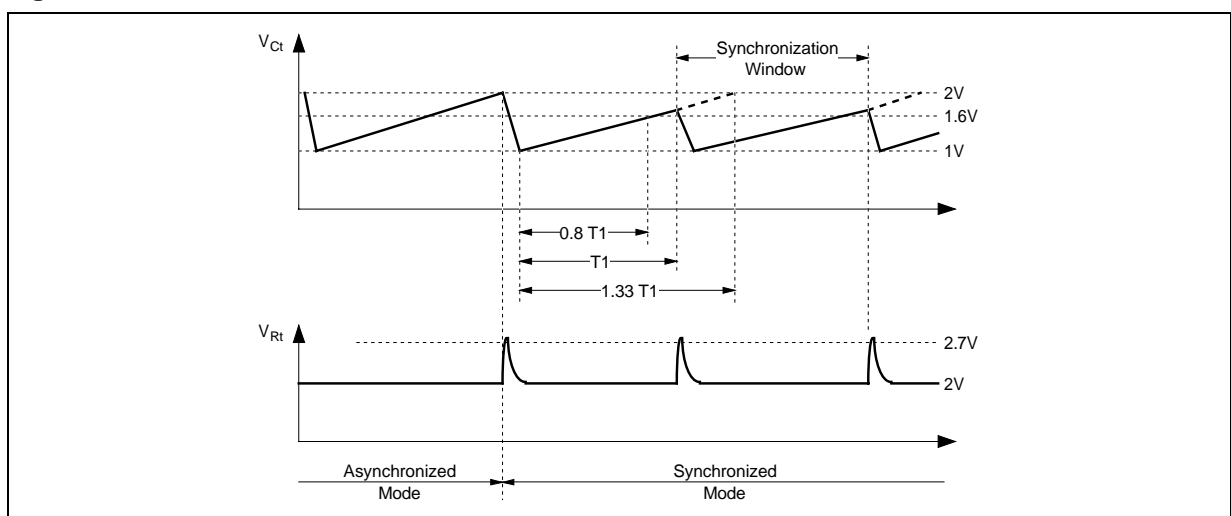
The internal current generator used to charge the "C<sub>t</sub>" capacitor is disabled for the entire phase where "V<sub>Rt</sub>" is higher than 2V. Thus, in order to maintain the saw-tooth shape of the oscillator signal, the "V<sub>Rt</sub>" voltage should fall to 2V before the capacitor "C<sub>t</sub>" full discharge.

**Figure 6**



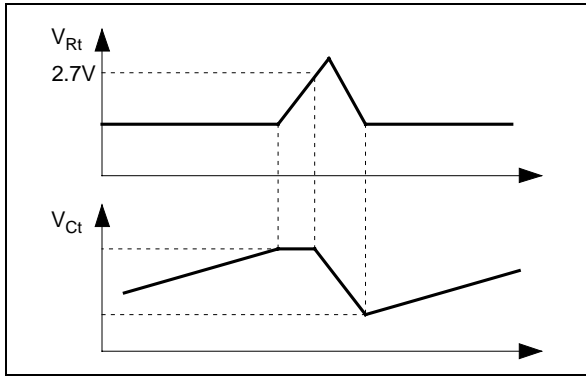
5170-16.EPS

**Figure 7**



5170-17.EPS

Figure 8



5170-18.EPS

III.3 - Error Amplifier (Figure 9)

The on-chip error amplifier can be accessed through its inverting and output terminals. The non-inverting input is internally tied to reference voltage level.

Comment :

An internal inverting amplifier sets the correct phase polarity of the error amplifier output signal for regulation.

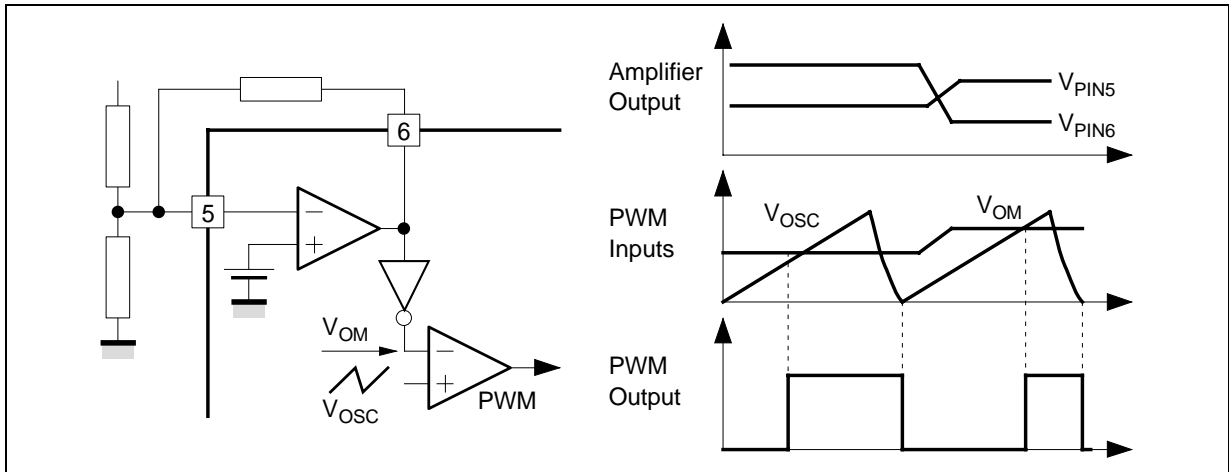
III.4 - Pulse Width Modulation (Figure 9)

The TEA 5170 is a PWM signal generator operating in voltage mode. The pulse width is determined by comparing the error signal "V<sub>OM</sub>" with the oscillator saw-tooth.

When the error signal "V<sub>OM</sub>" exceeds the regulation range, internal threshold components will set a minimum conduction time  $t_{ON (min)}$  and also limit the maximum conduction time  $t_{ON (max)}$ .

At initial start-up, a soft-start function implemented by linear charge of soft-start capacitor "C<sub>(S-START)</sub>" is used to vary gradually the  $t_{ON (max)}$  threshold. The output pulse width varies from  $t_{ON (min)}$  to  $t_{ON (max)}$  nominal value for V<sub>C(S-START)</sub> voltage variation of 0 to 2V.

Figure 9

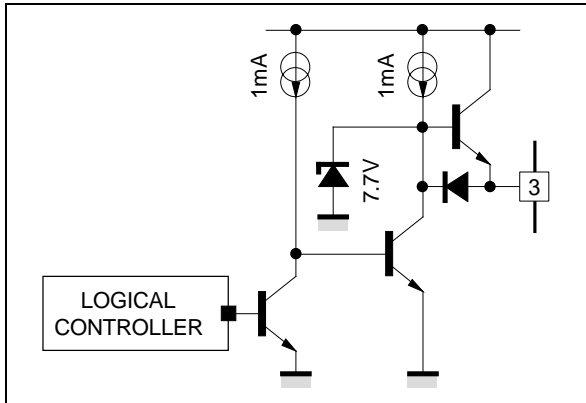


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**III.5 - Output Stage** (see Figure 10)

The output stage operates in on/off mode. For a supply voltage higher than 8V, the output signal value is independent of the supply voltage (typical value : 7V).

**Figure 10**



**III.6 - V<sub>CC</sub> Monitoring**

**V<sub>CC</sub> Rising :**

When V<sub>CC</sub> reaches the value "V<sub>CC (START)</sub>", an internal switch enables the operation of the output stage and the soft-start capacitor begins charging. The internal logic circuitry becomes operational before V<sub>CC</sub> has reached the "V<sub>CC (START)</sub>" value.

**V<sub>CC</sub> Falling :**

When V<sub>CC</sub> falls below the "V<sub>CC (STOP)</sub>" level, the negative output stage is switched-on, the transistor is turned off and the soft-start capacitor is discharged.

**IV - TV POWER SUPPLY APPLICATION BUILT AROUND TEA5170** (Figure 15)

General structure and operational features of this power supply were outlined in section 1.

The details covered below apply to a power supply configuration using the slave "TEA2164" device.

(Refer to TEA2164 data sheet and application note "AN409/0591" for further details).

**IV.1 - Main Application Characteristics**

| Characteristic                                    | Value                                    |
|---|--|
| Input voltage                                     | 170V <sub>AC</sub> to 270V <sub>AC</sub> |
| Output power                                      | 20W to 120W                              |
| Output power in stand-by mode                     | 1W to 6W                                 |
| Switching frequency                               | 32kHz                                    |
| Synchronization on line flyback signal (positive) |  |

**IV.2 - Components External To TEA5170**

*Component Value Calculation*

Also refer to TEA2164 Application Note "AN-409/0591" for calculation methods applicable to other power supply elements.

The external components determine the following parameters :

- Operating frequency
- t<sub>ON (min)</sub>
- Soft-start
- Error amplifier gain

*Ideal Values*

- Period of operation "T<sub>OSC</sub>" : 32μs
- t<sub>ON (min)</sub> duration : 1.2μs
- soft-start duration : 20ms
- Error amplifier gain :  
DC gain G<sub>DC</sub> = 35  
AC gain at 1/10 x T<sub>OSC</sub> : G<sub>AC</sub> = G<sub>DC</sub>/5 = 7

**IV.3 - Free-Running Oscillation Frequency**

For efficient use of TEA5170 and TEA2164 synchronization windows, the periods of both devices are determined as follows :

$$T_{OSC(5170)} = \frac{T_{SYNC}}{1.06}$$

$$T_{OSC(2164)} = \frac{T_{OSC(5170)}}{1.223}$$

Where :

- T<sub>SYNC</sub> : line flyback signal period
- T<sub>OSC(5170)</sub> : TEA5170 free-running period
- T<sub>OSC(2164)</sub> : TEA2164 free-running period

*Numerical Application*

Period of synchronization signal being

T<sub>SYNC</sub> = 32μs :

$$T_{OSC(5170)} = \frac{T_{SYNC}}{1.06} = 30.2\mu s$$

$$T_{OSC(2164)} = \frac{T_{OSC(5170)}}{1.223} = \frac{30.2}{1.223} = 24.7\mu s$$

The TEA5170 free-running period is determined as follows :

$$T_{OSC(5170)} = C_t (0.5 \times R_t + 1330)$$

Where :

$$C_t = \frac{t_{ON (min)} - 0.5 \times 10^{-6}}{1330}$$

- R<sub>t</sub> = 105kΩ (1%)
- C<sub>t</sub> = 560 pF (2%)

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## IV.4 - Error Amplifier Compensation

- A high DC gain is required for good accuracy.
- For stability reasons, the AC gain must be attenuated so as to avoid injection of the switching frequency component into the regulation loop.

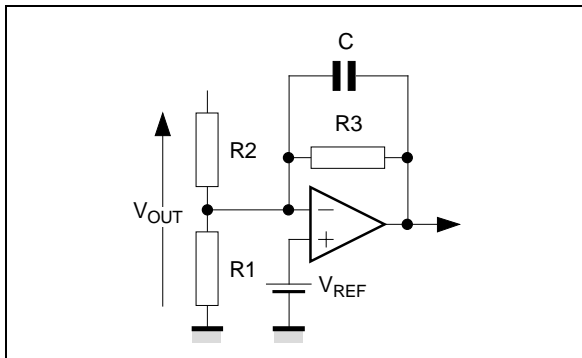
- DC Gain :  $G_{DC} = R3 \times \frac{R2 + R1}{R2 \times R1}$

- AC Gain :  $G_{AC} = \frac{R3 \times \frac{1}{j\omega C}}{R3 + \frac{1}{j\omega C}} \times \frac{R2 + R1}{R2 \times R1}$

### Assumptions :

- $R2 \gg R1$  since  $V_{OUT} > 10 V_{REF}$  so the value of  $R2$  does not modify the result of calculation and only  $R1$  and  $R3$  influence may be taken into consideration.
- $R1 = 2.2k\Omega$ ,  $R3 = 75k\Omega$
- With cut-off frequency in AC regulation mode :
- $f_c = \frac{1}{10 \times T_{osc}} \Rightarrow C = 2.2nF$

Figure 11

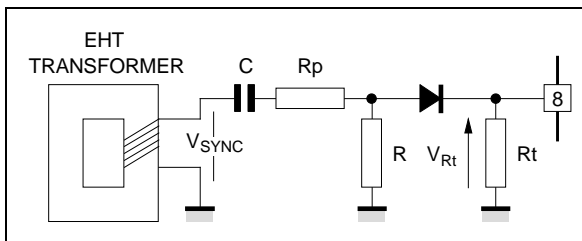


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## IV.5 - Synchronization Signal Matching Stage (Figure 12)

The synchronization signal is generated from the line flyback.

Figure 12



5170-22.EPS

The pulse amplitude is given by :

$$\frac{V_{8(max)}}{V_{SYNC}} = \frac{R}{R + R_p} \text{ With } R_t \gg R$$

The pulse time constant is  $(R + R_p)C$  and should be lower than the saw-tooth fall time.

Thus, for a line flyback signal amplitude of 50V :  
 $R = 6.8k\Omega$ ,  $R_p = 75k\Omega$ ,  $C = 150pF$

### Comment :

Practical and theoretical values may differ slightly since the rise time of the line flyback signal is not generally negligible.

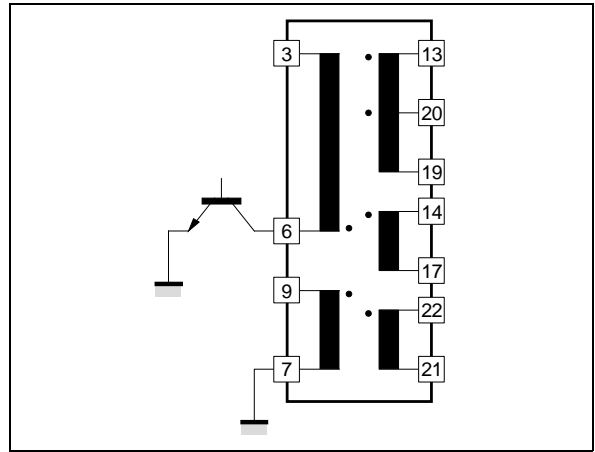
## IV.6 - Soft-Start Period Duration

In this application, the duration of soft-start is around 20ms,

With :

$$C_{(S-START)} = T_{(S-START)} \times 2 \times 10^{-6} = 47nF$$

Figure 13



5170-23.EPS

## IV.7 - Transformer Characteristics

(Reference : G4453-02 OREGA)

| Winding   | Pin   | Inductance  |
|-----------|-------|-------------|
| $n_p$     | 3-6   | 680 $\mu H$ |
| $n_{AUX}$ | 7-9   | 7 $\mu H$   |
| $n_2$     | 19-13 | 592 $\mu H$ |
| $n_3$     | 19-20 | 12 $\mu H$  |
| $n_4$     | 14-17 | 5 $\mu H$   |
| $n_5$     | 22-21 | 25 $\mu H$  |

## IV.8 - Operation

### IV.8.1 - Start-Up

The power supply of TEA5170 begins rising gradually upon initial start-up of the primary circuit. When  $V_{CC}$  reaches the value  $V_{CC(S-START)} = 4V$ , the oscillator has already begun running and the soft-start capacitor " $C_{(S-START)}$ " begins charging. The conduction time is  $t_{ON(min)}$  and rises gradually.



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### IV.8.2 - Stand-By

This function is externally activated by grounding the "stand-by" input thereby disabling the power supply of TEA5170. (Figure 15).

To return to normal mode of operation, this pin should be left floating.

### IV.8.3 - Synchronized Mode

The differentiator at synchronization input will transform the line flyback signal into a rectangular pulse whose time constant is around 1ms.

In this mode of operation, there is a lapse of time

between the falling edge of the synchronization signal and the real transistor turn-off (Figure 13).

In TV applications, this time should be less than the line flyback duration so as to avoid the occurrence of on-screen visible disturbances.

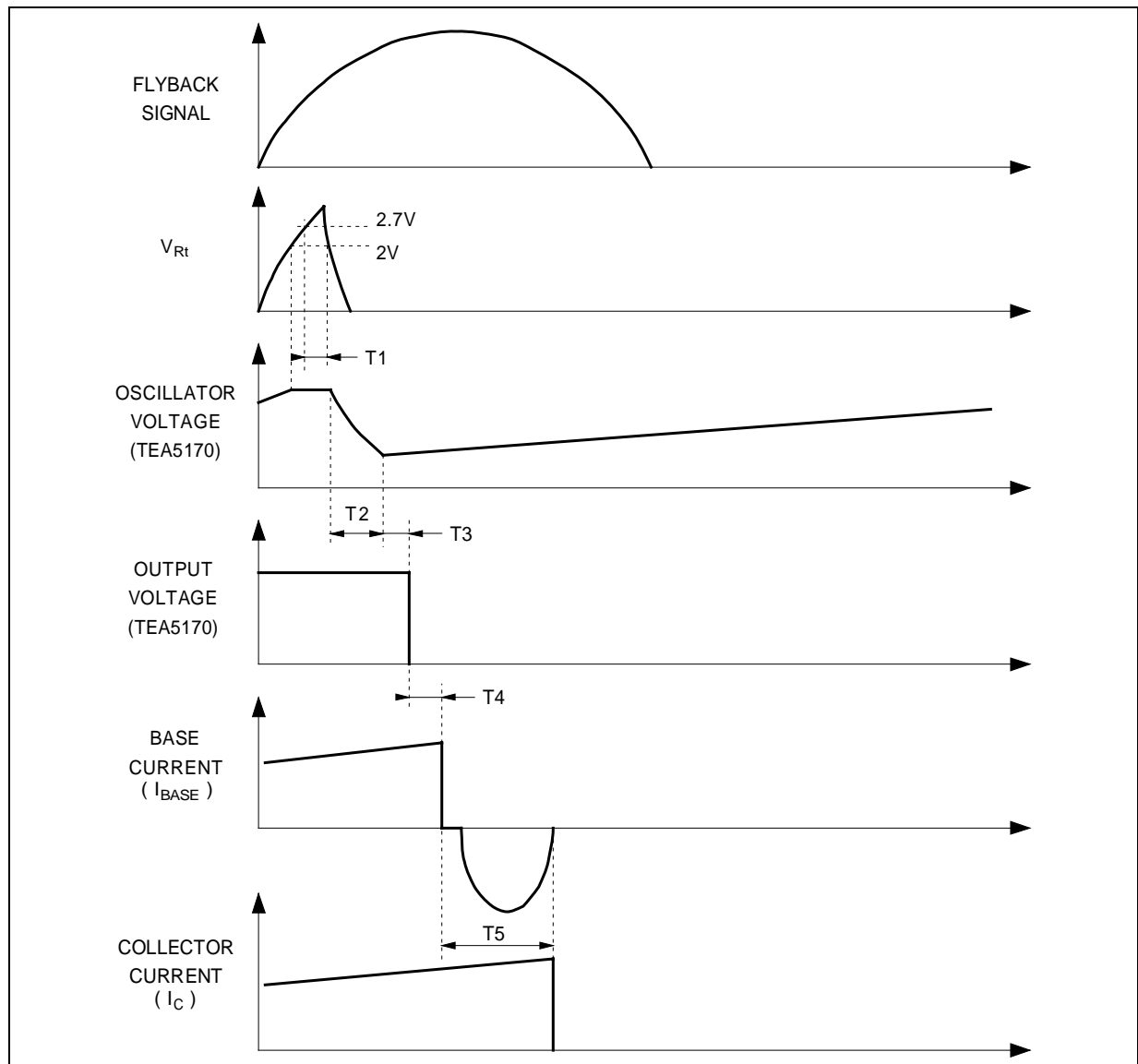
t1 and t3 times are specific to TEA5170  
(t1 + t3 = 800ns typ.)

t4 is specific to the primary circuit (= 800ns typ. with TEA2164).

Only t2 = t<sub>ON(min)</sub> and t5 = t<sub>STG</sub> of the switching transistor can be modified according to individual application requirements.

### IV.9 - Delay Time in Synchronized Mode

Figure 14

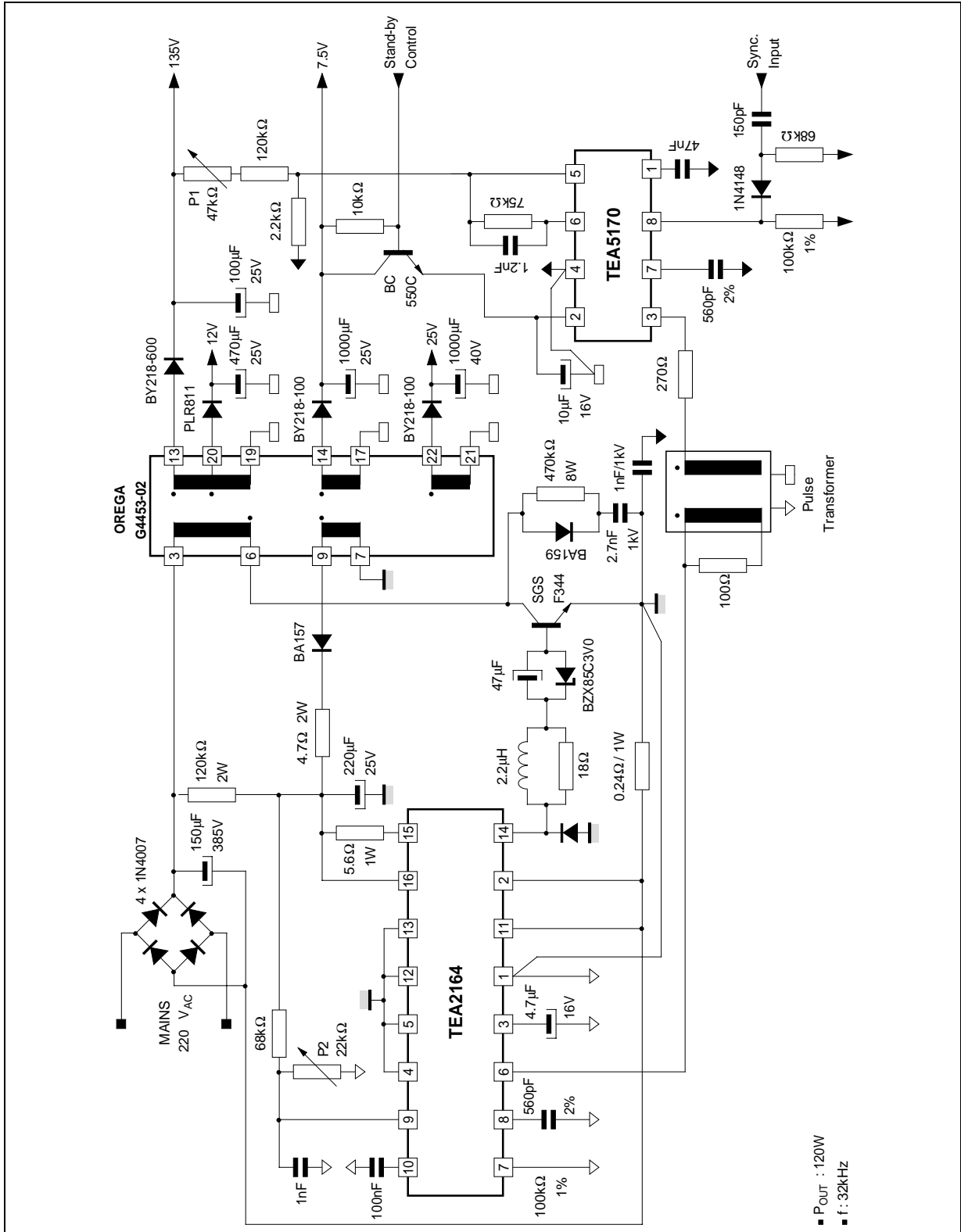


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## IV.10 - Electrical Diagram

Figure 15



5170-25-EPS

## TEA5170 - SECONDARY CONTROLLER FOR MASTER-SLAVE STRUCTURE

### V - DC-DC CONVERTER

( $9V \pm 40\% \Rightarrow 24V, 1.5W$ ) (Figure 16)

This low power converter employs a transformer wound on a low-cost ferrite former.

The configuration is protected against open loads and short-circuits.

#### Transformer characteristics

- Primary inductance :  $53.5 \mu\text{H}$
- Transformation ratio for 24V :  $n_s / n_p = 2$

#### Regulation Characteristics

- Line regulation at 4.9V to 15V :  $24V \pm 0.22\%$
- Load regulation for ( $0.4P_{\text{max}} - P_{\text{max}}$ ) :  $24V \pm 0.12\%$
- Power range : 0.24W to 1.6W
- Efficiency : 40%

### V.1 - Electrical Diagram

#### V.2 - Operation

- The period of operation is determined by  $R_t$  and  $C_t$  components.
- Minimum conduction duration :  $0.6 \mu\text{s}$
- Free-running period :  $29 \mu\text{s}$
- Soft-start period duration : preset at 100 ms.

#### V.2.1 - Open-load Protection

In case of low load values, the minimum conduction

time  $t_{\text{ON (min)}}$  with respect to the period of operation is too high to maintain the output voltage at its nominal value. The only solution to stabilize the voltage is to increase the period of operation by reducing the charge current of the oscillator capacitor  $C_t$ . This is obtained by injecting additional current into resistor  $R_t$  as soon as the output voltage  $V_{\text{OUT}}$  rises.

#### V.2.2 - Short-circuit Protection

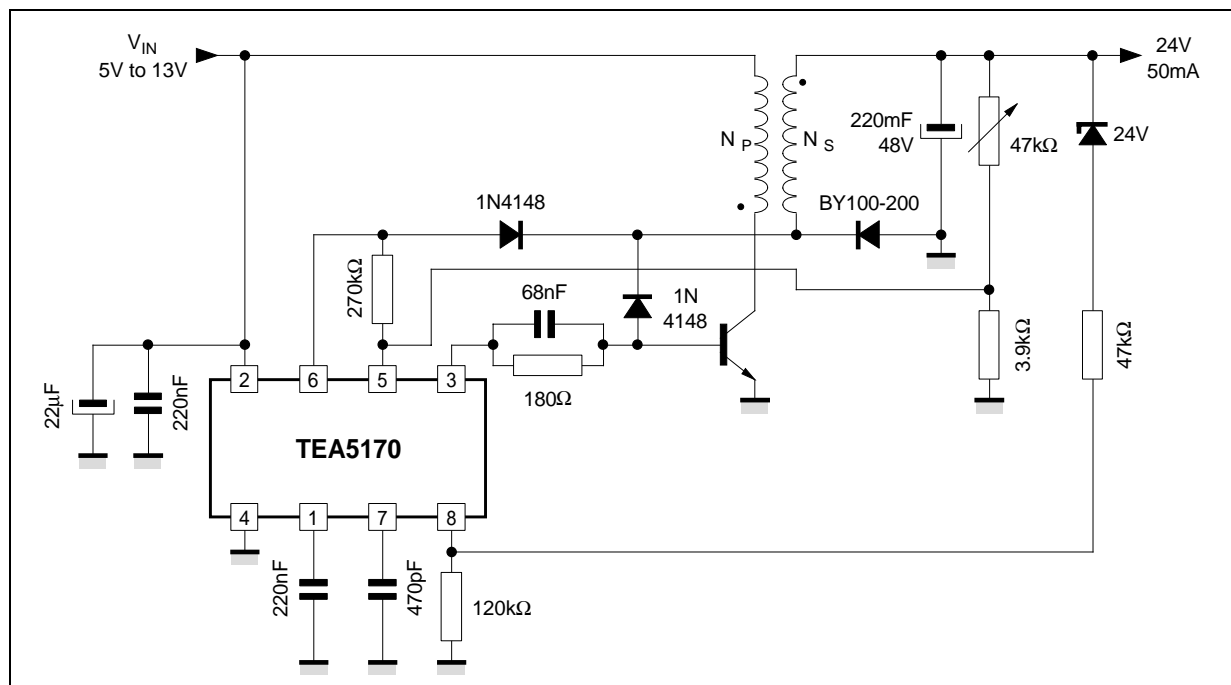
When the current through transistor becomes substantially high, the transistor is saturated and induces a high  $di_C/dt$ . The diode on switching transistor base is then forward biased and begins deviating a portion of the base current. This phenomenon is self amplified and therefore results in rapid transistor turn-off.

#### V.2.3 - Demagnetization Monitoring

In order to avoid magnetic flux runaway, the transistor should be driven into conduction only once the transformer has been fully demagnetized.

While the transformer is being demagnetized, the secondary-connected rectifier diode is forward biased and thus maintains the error amplifier output at 0 potential. The allowed conduction period is consequently  $t_{\text{ON (min)}}$ .

Figure 16



5170-26.EPS

## TEA5170 - SECONDARY CONTROLLER FOR MASTER-SLAVE STRUCTURE

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### VI - CONCLUSION

The TEA5170 requires a very simple configuration and yet offers excellent regulation quality combined with synchronization possibility for flyback-type converters.

The TEA5170 can be used in converters operating at 16kHz to over 100kHz frequency range.

Access to error amplifier and soft-start input are some of the remarkable features offered by this device whose application areas are by no means limited.

The TEA5170 belongs to the family of master controller devices characterized by their outstanding flexibility of use and application performances.

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