# THOMSON SEMICONDUCTORS

# UAA4006A

## SWITCH MODE POWER SUPPLY CONTROL CIRCUIT

The UAA4006A is a regulation and control device for fly-back switch mode power supplies using one external switching transistor.

- Includes oscillator, PWM and error amplifier
- Soft start
- Direct drive of the switching transistor
- Self-regulated positive base current (peak 1.5 A)
- Negative base current providing fast turn-off and allowing the best use of the safe operating area (peak 1.5 A)
- Switching transistor protected against saturation failure
- Instantaneous collector current limitation
- Positive power supply monitoring
- On chip thermal protection
- Adjustable minimum conducting time for use of a snubber circuit
- Internal reference voltage
- Start up with very low supply current

* Application note available AN027R1

### ORDERING INFORMATION

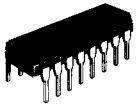
| PART NUMBER | PACKAGE | |
|---|---|---|
| | DP | SP |
| UAA4006A | • | • |

**Example** : UAA4006ADP

## SWITCH MODE POWER SUPPLY CONTROL CIRCUIT

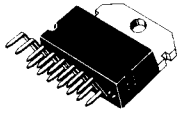
### CASES

**CB-79**



**DP SUFFIX**
PLASTIC PACKAGE

**CB-501**

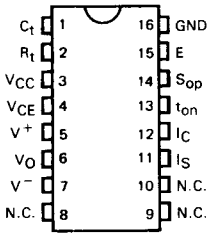


**SP SUFFIX**
PLASTIC PACKAGE

### PIN ASSIGNMENTS

(Top view)

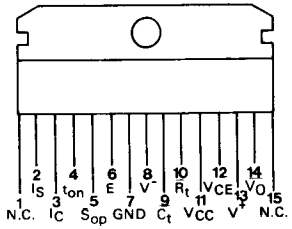
**CB-79**




| | |
|---|---|
| $C_t$ | : Oscillator timing capacitor |
| $R_t$ | : Oscillator timing resistor |
| $V_{CC}$ | : Supply voltage |
| $V_{CE}$ | : $V_{CE(sat)}$ sensing |
| $V^+$ | : Power stage positive supply |
| $V_O$ | : Power stage output |
| $V^-$ | : Power stage negative supply |
| $I_S$ | : Secondary current monitoring input |
| $I_C$ | : Primary current limit input |
| $t_{on}$ | : $t_{on(max)}$ limit access |
| $S_{op}$ | : Amplifier output |
| E | : Amplifier input |
| GND | : Ground |

(Front view)

**CB-501**




Ref. 00420

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THOMSON COMPONENTS

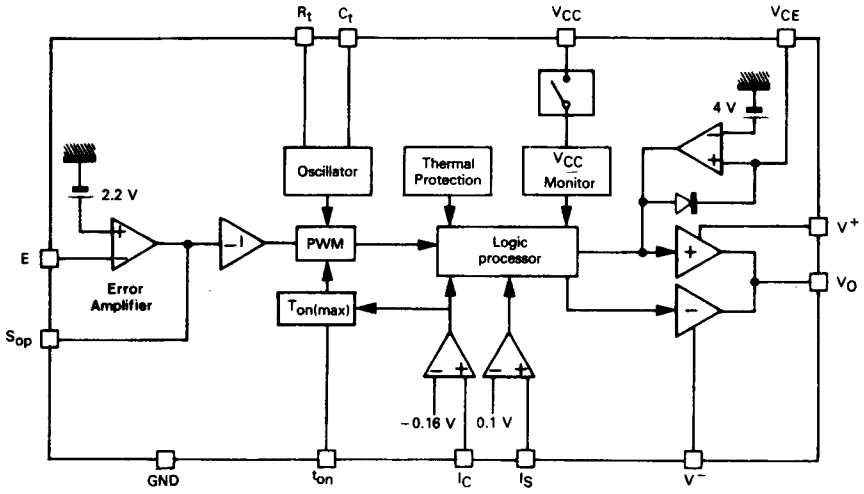
## MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Supply voltage | $V_{CC}$ | +15 | V |
| Supply voltages (Power stage) Positive<br>Negative | $V^+$<br>$V^-$ | +15<br>−6 | V<br>V |
| Voltage between pins 11 and 13 | $V^+ - V^-$ | +18 | V |
| Output current | $I_O$ | ±1.6 | A |
| Current into input $I_C$ (internal protection diodes) | – | ±5 | mA |
| Current into input $I_S$ | – | ±5 | mA |
| Minimum value of resistance $R_t$ | $R_{t(max)}$ | 18 | kΩ |
| Junction temperature range | $T_j$ | −40 to +150 | °C |
| Storage temperature range | $T_{stg}$ | −40 to +150 | °C |

## THERMAL CHARACTERISTICS

| Characteristic | Symbol | CB-79 | CB-501 | Unit |
|---|---|---|---|---|
| Junction-ambient thermal resistance | $R_{th(j-a)}$ | 50 | 40 | °C/W |
| Junction-case thermal resistance | $R_{th(j-c)}$ | 7 | 2.5 | °C/W |

## BLOCK DIAGRAM




| CASE | $C_t$ | $R_t$ | $V_{CC}$ | $V_{CE}$ | $V^+$ | $V_O$ | $V^-$ | NC | $I_S$ | $I_C$ | $t_{on}$ | $S_{op}$ | E | GND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CB-79 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8, 9, 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| CB-501 | 9 | 10 | 11 | 12 | 13 | 14 | 8 | 1, 15 | 2 | 3 | 4 | 5 | 6 | 7 |

## CIRCUIT DESCRIPTION

### OSCILLATOR

The oscillator provides a triangular waveform with a fall time much smaller than the rise time. The voltage swings between +1.5 V and about $V_{CC}/2$. The maximum operating frequency is 60 kHz, the period being given by $T_{osc} = 0.5 R_t C_t$ Resistor $R_t$ adjusts the frequency, but determines also the value of $t_{on(min)}$ (see logic processor).

### PULSE WIDTH MODULATOR (PWM)

The variable duty-cycle signal is elaborated by comparing the oscillator voltage (pin $C_t$) to the inverted error amplifier output voltage. Another comparator determines the maximum value of the duty-cycle by comparing the oscillator signal with the voltage on pin "$t_{on}$". If $V(t_{on}) = 0$, then the maximum duty-cycle is internally set to 0.9 $T_{osc}$, otherwise, the maximum duty-cycle is given by :

$$\left(\frac{t_{on}}{T_{osc}}\right) max = 1 - \frac{R_{ton}}{2R_t}$$

(valid only if $Rt_{on} > 0.2\ R_t$, where $Rt_{on}$ is the resistor inserted between $t_{on}$ pin and ground).

### CURRENT LIMITATION

A level lower than −0.15 V on pin $I_C$ involves two actions :
- a direct action through the logic processor which stops the drive until the end of the oscillator period ;
- an indirect action through the $t_{on}$ funtion. The change of state at the output of comparator $I_C$ is applied to pin $t_{on}$ as long as the overload current persists. By inserting capacitor $C_B$ between pin $t_{on}$ and $V_{CC}$ (about 0.1 µF), the voltage at this point rises by a quantity ΔV proportional to the duration and the frequency of the overcurrent.

This will consequently lower the maximum conduction ratio, thus decreasing the frequency of the overcurrent. At the end of an overload condition, capacitor $C_B$ slowly charges up through a 20k internal impedance, in order to return progressively to normal operation.

NOTE : If capacitor $C_B$ is omitted, direct action will only be implemented.

### SUPERVISION OF THE SECONDARY CURRENT

In order to avoid the magnetization of the transformer core in case of short-circuits or heavy overloads on the secondary winding, a new cycle of conduction can only begin after the secondary current has completly fallen to zero.
This task is accomplished by comparator $I_S$ whose threshold is 0.1 V and detects the zero crossing of the secondary current.

### PROTECTION AGAINST DESATURATION

If, because of a too low base current or a too heavy load, the collector to emitter voltage of the switching transistor rises above 4 V approximately, the output of comparator $V_{CE}$ changes state, and the drive is interrupted.

### ERROR AMPLIFIED

This is an operational amplifier whose open loop gain is about 1000. The input current are less than 3 µA, and the input offset voltage is lower than 5 mV.
The input common-mode voltage range is 0 V to ($V_{CC}$ − 3 V). Due to an internal limitation the output source current of the amplifier can not exceed 2 mA.

### START SWITCH

An internal switch is inserted between pin $V_{CC}$ supply line and internal voltage.
During power-up, this switch closes when $V_{CC}$ reaches +7.2 V. The leakage current ($I_{CC}$)L is about 0.4 mA before the switch closes. This original feature enables starting the converter by means of a high value resistance directly connected between $V_{CC}$ and the high supply voltage. The smoothing capacitor on $V_{CC}$ supply provides the energy required for the start. The turn-off of the internal switch requires that $V_{CC}$ falls below +6.2 V.

### THERMAL PROTECTION

This protection becomes active when the junction temperature reaches +160°C.

### LOGIC PROCESSOR

A logic unit processes the information coming from the fault detectors, and ensures that the output signal fulfils two conditions :

- No double pulsing with a period : the occurrence of a hault detection is memorized until the end of the period.
- To allow the discharge of a snubber network, the minimum width of the output pulse is set at a given value $t_{on(min)}$ by an internal monostable. If this monostable is not triggered, there will be no conduction. The duration $t_{on(min)}$ is programmable by resistor $R_t$ using the relationship :

$$t_{on(min)}\ (\mu s) = 0.144\ R_t\ (k\Omega) - 2 \text{ @ } (V_{CC} = +12\ V)$$

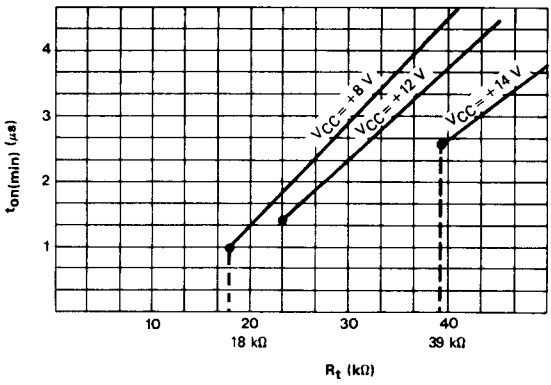
## ELECTRICAL CHARACTERISTICS

$T_{amb} = +25°C$, $V_{CC} = \pm 10$ V, $V^- = -5$ V
(Unless otherwise specified)

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Supply voltage | $V_{CC}$ | – | – | 14 | V |
| Rise supply voltage threshold | $V_{CCR}$ | 6.5 | 7.2 | 7.9 | V |
| Fall supply voltage threshold | $V_{CCF}$ | 5.3 | 6.0 | 6.7 | V |
| Hysteresis on $V_{CC}$ threshold | $\Delta V_{CC}$ | 1 | 1.2 | 1.7 | V |
| Current $I_{CC}$ ($V_{CC}$ under threshold voltage) | – | – | 0.4 | 1 | mA |
| Supply current ($V_{CC} = +10$ V) | $I_{CC}$ | – | 10 | – | mA |
| Positive supply voltage (Power stage) | $V^+$ | 4 | – | 15 | V |
| Negative supply voltage (Power stage) | $V^-$ | −6 | – | −1 | V |
| Threshold of input $I_C$ | $I_{C(th)}$ | −0.176 | −0.16 | −0.144 | V |
| $I_C$ input current ($V_{(I_C)} = 0$ V) | – | – | 5 | 20 | µA |
| Threshold of input $I_S$ | $I_{S(th)}$ | 0.065 | 0.1 | 0.135 | V |
| $I_S$ input current ($V_{(I_S)} = 0$ V) | – | – | 5 | 20 | µA |
| Error amplifier open-loop gain | $A_V$ | 60 | – | – | dB |
| Error amplifier offset voltage | $V_{IO}$ | – | 5 | – | mV |
| Internal reference voltage | $V_{(ref)}$ | 2.1 | 2.2 | 2.3 | V |
| Oscillator frequency $f_{osc} = \frac{1}{T_{osc}}$ | $f_{osc}$ | – | $2/R_tC_t$ | 60 | kHz |
| Value of resistance $R_t$ ($V_{CC} = +14$ V) (See figure 1)<br>($V_{CC} = +8$ V) | $R_t$ | 39<br>18 | 50<br>50 | 100<br>100 | kΩ |
| Output current ($V^+ - V_S = 3$ V, $V_S - V^- = 3$ V) | $I_O$ | ±1.5 | – | – | A |
| $V_{CE}$ comparator threshold voltage | $V_{CE(th)}$ | 3.6 | 4 | 4.4 | V |
| $t_{on(min)}$ adjustment range ($V_{CC} = +14$ V) (See figure 1)<br>($V_{CC} = +8$ V) | – | 4<br>1 | –<br>– | 8<br>13 | µs |
| Max duty cycle : $\left(\frac{t_{on}}{T_{osc}}\right)_{max}$ ($R_{t_{on}} > 0.2\ R_t$) - Note 1<br>($R_{t_{on}} < 0.2\ R_t$) | –<br>– | –<br>– | $1 - \frac{R_{t_{on}}}{2R_t}$<br>0.9 | –<br>– | –<br>– |
| Oscillator frequency drift with temperature ($V_{CC} = 12$ V) | – | – | 0.02 | 0.05 | %/°C |
| Oscillator frequency drift with $V_{CC}$ | – | – | 0.2 | 0.5 | %/V |

**Note 1** : $R_{t_{on}}$ externally connected between pin "$t_{on}$" and GND
$R_t$ externally connected between pin "$R_t$" and GND

**FIGURE 1 - $t_{on(min)}$ ADJUSTMENT RANGE**



## OUTPUT STAGE

### ON-state

The positive stage achieves a very efficient drive of the switching transistor.
Its features are essentially :

- Direct drive (neither inductor, nor tranformer) ;
- The transistor stays in a quasi-saturation mode, and thus has a reduced storage time ;
- The drive energy is strictly limited to the required amount ;
- Easy implementation.

$K_1$ is closed to turn the positive stage on. The maximum value of the positive base current is determined by the external limitation resistor R (between $V_{CC}$ and $V^+$).
Diode D maintains Q in a quasi-saturation mode : the more Q is saturated, the more diode D will shunt an important part of the drive current $I_{B1}$, through diode $D_1$.
Resistor $R_B$ has a low value (about 1 Ω), and is used to stabilize the regulation loop. For a good efficiency of the negative drive, the value of this resistor should be as low as possible.
Integrated Darlington $T_1$ is able to supply a peak current of 1.5 A with a 2 V saturation voltage.
The voltage $V_{CE}$ on transistor Q is :
$V_{CE} = V_D + R_B I_{B1}$

### OFF-state

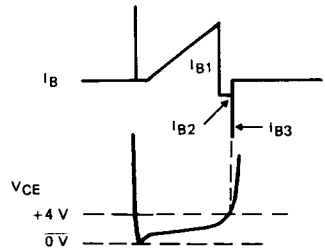
The turn off is accomplished in two steps :

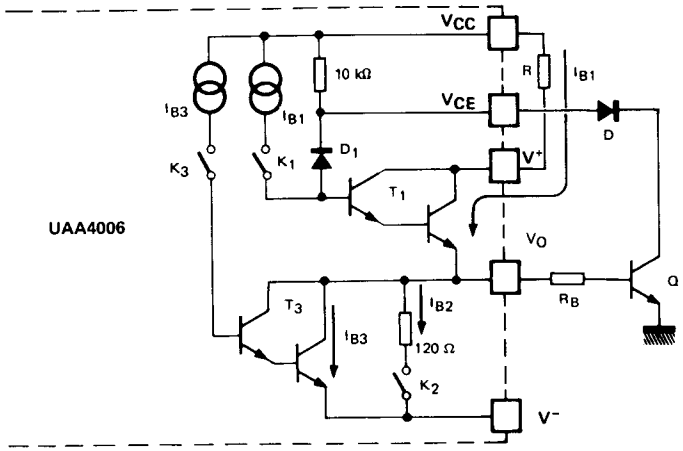
- an immediate action through $K_2$ which connects the base of the switching transistor to the negative supply through a 120 Ω integrated resistor (current $I_{B2}$) :
- a detayed action through $K_3$ which is closed only after the desaturation of the external transistor. This is detected by comparator $V_{CE}$, when the collector to emitter voltage reaches 4.5 V.

Darlington $T_3$ can supply 1.5 A with a 2 V saturation voltage (current $I_{B3}$).

**NOTE** : The negative drive $I_{B3}$ for the removal of the stored charges is delayed in order to limit the slope $dI_B/dt$ at the on-off transition. A high $dI_B/dt$ might indeed lead to a destructive overheating of the base-collector junction (see "The power transistor in its environment" published by Thomson-CSF Division Semiconducteurs Discrets).

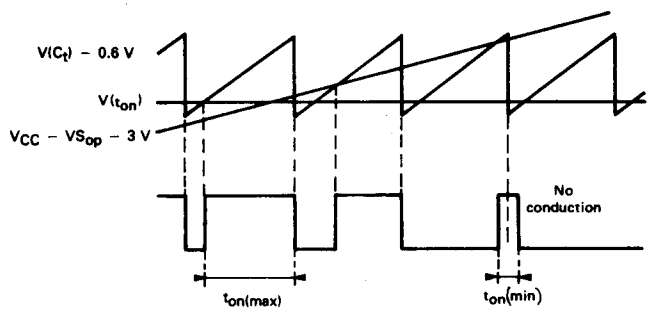
**SELF REGULATED BASE CURRENT $I_B = f(V_{CE})$**



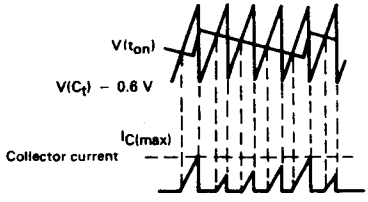



## TYPICAL WAVEFORMS

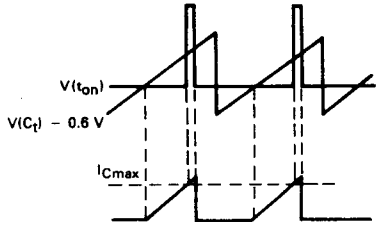
### LIMITS OF THE DUTY CYCLE



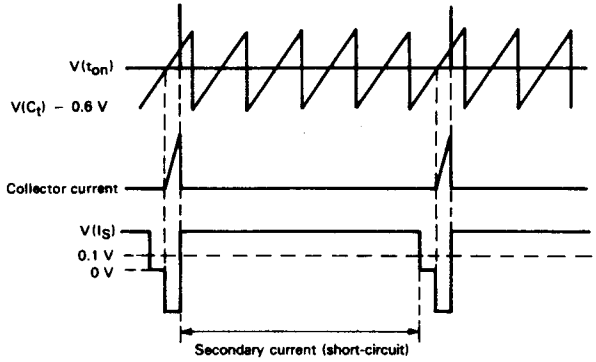

### CURRENT LIMITATION



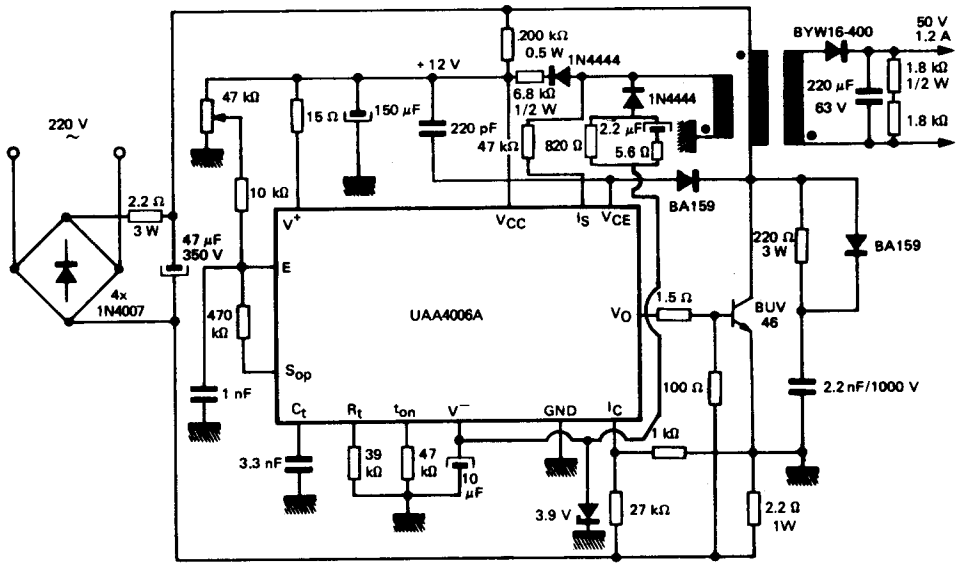

WITH $C_B$ CAPACITOR




WITHOUT $C_B$ CAPACITOR

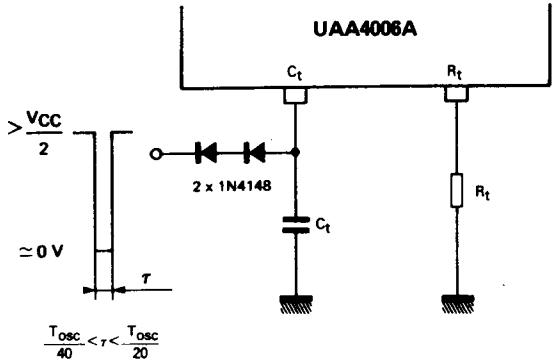


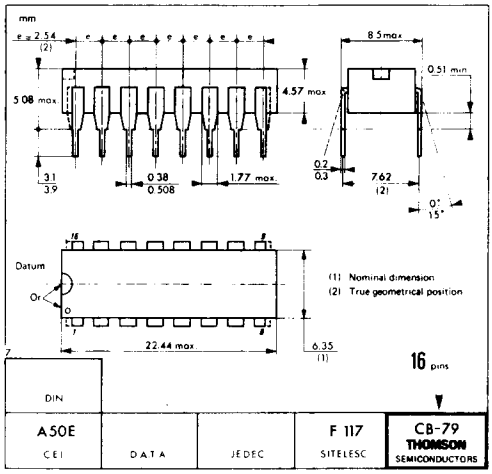
## 50 W FLY-BACK CONVERTER



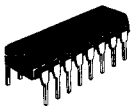

## EXTERNAL SYNCHRONIZATION

The oscillator may be synchronized to an external frequency $f_{ext}$ so that : $f_{osc} < f_{ext} < 1.2\ f_{osc}$

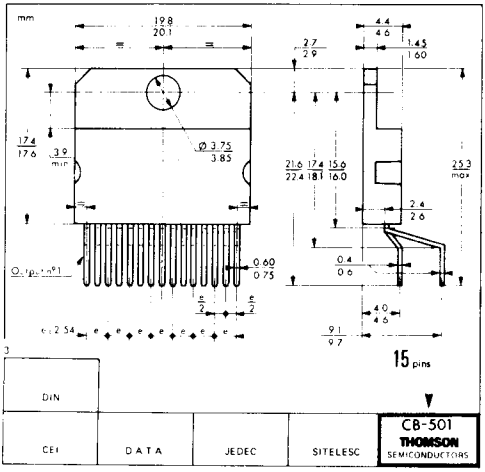




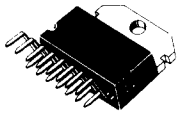

**CB-79**



**DP SUFFIX**
PLASTIC PACKAGE




**CB-501**



**SP SUFFIX**
PLASTIC PACKAGE

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