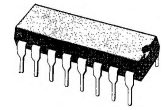
SGS-THOMSON MICROELECTRONICS

UAA4002

CONTROL CIRCUIT FOR FAST SWITCHING TRANSISTORS

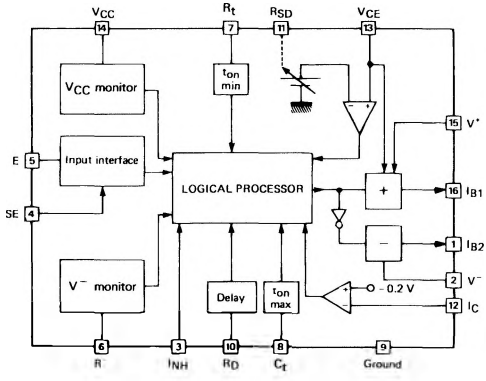
- DIRECT DRIVE OF THE SWITCHING TRANSISTOR
- SELF REGULATED POSITIVE BASE CURRENT (1 A max)
- NEGATIVE BASE CURRENT ENSURING FAST TURN-OFF (3 A max)
- THE OUTPUT CURRENT CAN BE INCREASED BY MEANS OF ONE (or more) EXTERNAL TRANSISTOR(S)
- MINIMUM CONDUCTING TIME (or no conduction) TO ALLOW THE DISCHARGE OF A RDC NETWORK
- PROTECTION AGAINST SATURATION FAILURE OF THE POWER TRANSISTOR DURING CONDUCTING PERIOD, WITH ADJUSTABLE DETECTION THRESHOLD
- INSTANTANEOUS-COLLECTOR CURRENT LIMITATION
- POSITIVE SUPPLY (V_{CC}) MONITORING
- NEGATIVE SUPPLY MONITORING WITH ADJUSTABLE THRESHOLD
- ON-CHIP THERMAL PROTECTION
- PROGRAMMABLE MAXIMUM ON TIME
- TTL AND CMOS COMPATIBLE INPUT
- CAN BE DRIVEN WITH ALTERNATE PULSES
- ADJUSTABLE DELAY BETWEEN THE RISING EDGE OF THE INPUT SIGNAL AND THE BEGINNING OF THE POSITIVE BASE DRIVE



DIP-16/2

ORDER CODE : UAA4002DP

Figure 1: Block Diagram



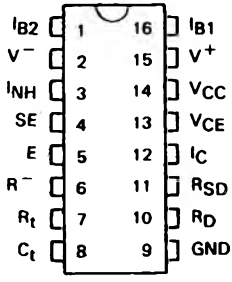
I_{B2}	:	Output sink current
V^-	:	Negative power supply (power stage)
I_{NH}	:	Inhibition input
S_E	:	Input selection
E	:	Input
R^-	:	Negative supply monitoring time resistor
R_t	:	Minimum conducting time resistor
C_t	:	Minimum conducting time capacitor
I_{B1}	:	Output source current
V^+	:	Positive power supply (power stage)
V_{CC}	:	Positive supply voltage
V_{CE}	:	$V_{CE(sat)}$ sensing
I_C	:	Collector current monitoring input
R_{SD}	:	$V_{CE(sat)}$ threshold voltage monitoring
R_d	:	Delay time resistor
G_{ND}	:	Ground

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_{CC}	Supply Voltage	+ 15	V
V^+	Positive Supply Voltage (power stage)	+ 15	V
V^-	Negative Supply Voltage (power stage)	− 10	V
$V^+ - V^-$	Voltage between Pins 15 and 2	+ 18	V
I_{B1}	Positive Output Current	+ 1.5	A
I_{B2}	Negative Output Current	− 3.5	A
I_C	Current into Input I_C (internal protection diodes)	± 5	mA
−	Minimum Value of Resistors R_t and R_D	5	kΩ
−	Voltage between Input and V^-	+ 18	V
T_j	Junction Temperature Range	− 40 to + 150	°C
T_{stg}	Storage Temperature Range	− 40 to + 150	°C

Note : 1. Pin 2 (V-) should not be left open.

PIN CONNECTION (top view)



I_{B2} : Output sink current
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R_d : Delay time resistor
G_{ND} : Ground

THERMAL DATA

$R_{th(j-a)}$	Maximum Junction-ambient Thermal Resistance	80	°C/W

ELECTRICAL CHARACTERISTICS

T_{amb} = + 25 °C, V_{CC} = + 10 V, V^- = – 5 V (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{CC}	Supply Voltage	7	–	14	V
–	Positive Supply Voltage Monitoring Threshold	–	7	–	V
I_{CC}	Supply Current	–	12	–	mA
V^+	Positive Supply Voltage (power stage)	4	–	14	V
V^-	Negative Supply Voltage (power stage)	– 1	–	– 9	V
V_I	Threshold of Input I_C	0.160	0.2	0.240	V
I_I	Current into Input I_C	–	5	20	µA
R_t	Value of Resistor R_t (R_t between pin 7 and ground)	10	47	200	kΩ
R_D	Value of Resistor R_D (R_D between pin 10 and ground)	20	–	200	kΩ
I_{B1}	Positive Output Current ($V_{(15)} - V_{(16)}$ = + 2 V)	0.5	–	–	A
$I_{B1(peak)}$	Positive Output Current (peak value)	1	–	–	A
I_{B2}	Negative Output Current ($V_{(1)} - V_{(2)}$ = + 4 V)	3	–	–	A
V_{SD}	Comparator V_{CE} Threshold Voltage	1	–	5.6	V
–	High Level on Input E ($V_{(5)} - V^-$ < + 18 V)	2	–	V_{CC}	V
–	Low Level on Input E (input SE not connected)	V^-	–	0.8	V
–	Low Level on Input E ($\|V^-\|$ > 2.5 V, input SE tied to ground)	V^-	–	– 2	V
–	Current into Input E ($V_{(5)}$ = 0 V) Input SE Left Open Input SE Grounded	 – –	 10 0.2	 50 0.3	 µA mA
–	Low Level on Input I_{NH}	0	–	0.8	V
–	High Level on Input I_{NH}	2	–	V_{CC}	V
$t_{on(min)}$	Time Constant t_{on} min (R_t between pin 7 and ground)	0.06 R_t (kΩ)			µs
t_d	Delay between Input Pulse and Rise of Output Current (R_D between pin 10 and ground)	0.05 R_D (kΩ)			µs
–	Propagation between Input Pulse and Rise of Output Current	0.3			µs
V_{SD}	Desaturation Threshold (R_{SD} between pin 11 and ground)	$10 \times \frac{R_{SD}}{R_t}$			V
R^-	V^- min Detection Resistor Value (R^- between pin 6 and V^-)	$\frac{R_t}{2}\left(1 + \frac{V^- min}{5}\right)$			Ω
$t_{on(max)}$	Time Constant t_{on} max (C_t between pin 8 and ground)	$2R_tC_t$			s
–	Thermal Shut Down	150			°C

APPLICATION INFORMATION

The coexistence of a power circuit handling high voltages and currents, and a control circuit carrying low amplitude signals, does not represent any special difficulty provided that a few simple rules are observed.

Positive and negative supply voltages of the integrated circuit must be carefully filtered by means of capacitors located very close to the device.

The device itself must by situated close to the power transistor, using short connections.

The control circuit ground (pin 9) and the power circuit ground (emitter of the power transistor) must be linked by a single connection, as short as possible and of adequate cross-section.

A ground plane on the printed circuit board may be favourable in noisy environments. With regards to upper switches of a bridge configuration, the auxiliary supplies of the integrated circuit must have a low parasitic capacitor with respect to the ground potentiel. In the same way, the isolated components

driving the UAA4002 (optocoupler or pulse transformer) must have also a low parasitic capacitor in order to reduce dv/t phenomenons and to avoid risks of reswitching or conduction cut-off.

If a free-wheel diode is connected in parallel with the power transistor (witch is generally the case in bridge systems), a diode (1N4148) must be connected between pin 13 and ground (cathode on pin 13 and anode on ground) in order to limit the negative voltage applied to this pin during the conduction of the free-wheel diode.

CIRCUIT DESCRIPTION (see block diagram figure 1)

INPUT INTERFACE E AND SE INPUT

It translates the input signal into the logic levels required by the internal processor.

It also includes a RS flip-flop for the pulse mode operation.

FAULT DETECTORS

- Power transistor collector current limiting (I_C input)

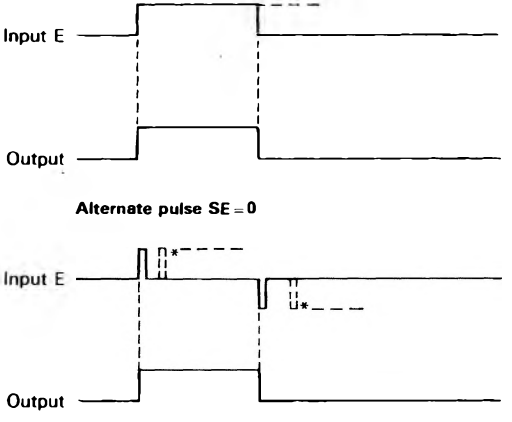
The collector current of the power transistor is measured by means of a shunt connected in the negative return of the power supply. As a result the current rather than the emitter current, since the base current of the switching does not flow through the shunt.

A voltage below - 0.2 V on input I_C causes comparator to change state. This information is transmitted to the logic unit, which blocks the output pulses from the circuit until the next positive transition of the input signal.

If the voltage across the measuring shunt exceeds 0.2 V for the required limiting current value, a voltage divider bridge may be used (see application note NA031A).

If input I_C not used, it must be connected directly to ground.

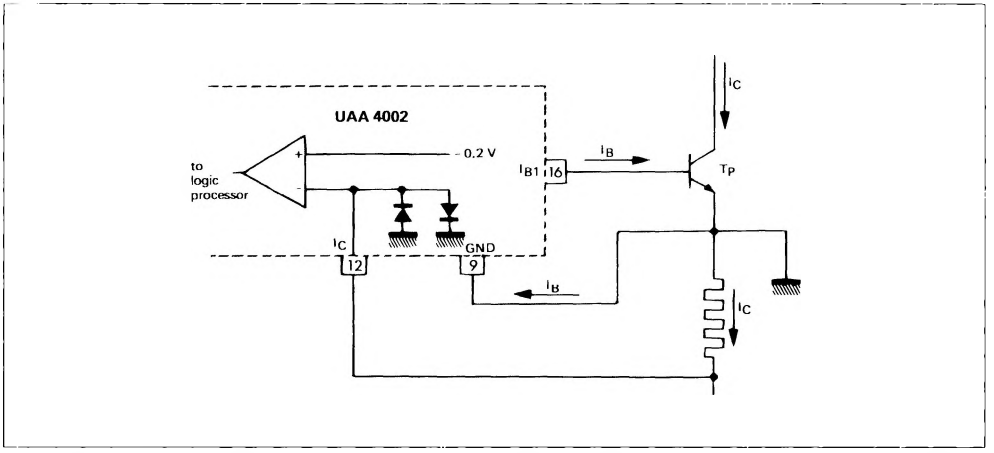
Figure 2 : Level Mode SE = 1.



* These parasitic pulses are not taken into account.

Note : Pulse duration > 100ns.

Figure 3 : Switching Transistor Collector Current Measurement.



- Protection against desaturation of the power transistor.

A comparator monitors continuously during the conduction that the collector voltage on the switching transistor remains lower than the preset value.

The preset value V_{RSD} (see figure 4) is given by :

$$R_{SD} = 5\ V \times 2 \frac{R_{SD}}{Rt}$$

Current I set by external resistor R_t is :

$$I\ (mA) = \frac{5\ (V)}{R_t\ (k)}$$

Without resistor R_{SD}, the threshold is set internally at + 5.6 V.

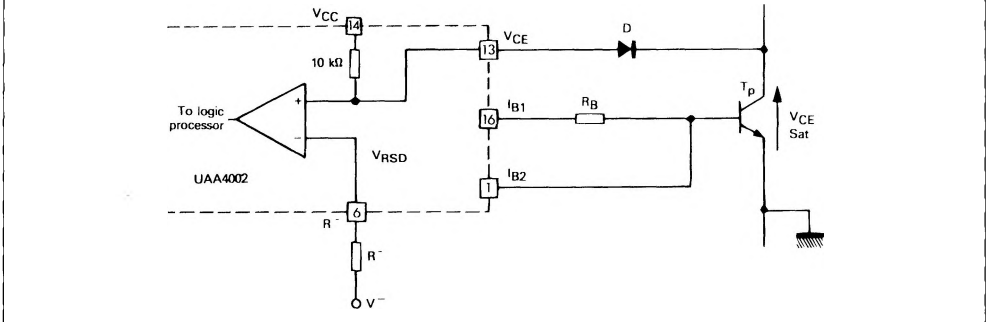
In case of overstep, the information is transmitted to the logic unit, which turns the output off until the next positive edge of the input signal.

To enable the switching transistor collector emitter voltage to fall when conduction begins, the protection function against desaturation is disabled during t_{on} min (see application note NA031A).

This protection is disabled by connecting pin R_{SD} directly to V.

(FOR THRESHOLD EXCEEDING 5.5 V SEE NA031EA).

Figure 4 : V_{CEsat} Voltage Monitoring.



Diode D must be a high-speed diode able to withstand the transistor collector-emitter volatge when the transistor is cut-off.

SUPPLY DEFECT

- Negative supply (R input, see figure 4).

It is possible to disable the output pulses if the negative supply voltage V is insufficient to guarantee the switching of the power transistor (optional).

(FOR USING WITHOUT NEGATIVE POWER SUPPLY SEE NA031A)

For this a resistor R is tied between pin 6 and the negative supply.

A current 2 I flows into it, and the threshold of the detector is + 5 V on pin 6.

Thus giving the relationship :

$$\frac{5 + V_{-\,min}}{R_-} = 2 \times \frac{5}{R_t} \qquad R_- = \frac{R_t}{2}\left(1 + \frac{V_{-\,min}}{5}\right)$$

This function can be disabled ty tying pin 6 to ground.

- Positive supply (V_{CC} input)

An internal comparator ensures that there is no output voltage if positive supply V_{CC} is less than + 7 V. This threshold is not adjustable.

- Inhibition (I_{NH} input)

The action of the inhibition input is shown in the diagram below.

This input is CMOS and TTL compatible. If not used, it must be connected directly to ground.

- Thermal protection

The UAA4002 is protected against excessive overheating by a thermal cut-out which automatically cuts off the output pulses if the chip temperature exceeds + 150 °C. The interruption is stored for a complete conduction period, but the output pulses reappear as soon as the chip temperature falls below the limiting temperature value.

TIME CONSTANTS

- Minimum conducting time (R_t input)

To enable the capacitor of the switching aid network associated with power transistor to discharge completely, the logic processor ensures that the integrated circuit output pulse has a minimum duration t_{on} min. To be effective, this must be at least four times the time constant of the RDC network.

The value of t_{on} min is programmed by a resistor R_t

Typically t_{on} min (s) = 0.06 x R_t (k)

The usable range of values for t_{on} min is between 1 and 12 s.

Resistor R_t has a key role in the operation of the UAA4002 integrated circuit. It sets the value of a bias current internal to the circuit :

$$I\,(mA) = \frac{5}{R_t\,(k)}$$

t_{on} min embodies a priority function : no other security function can stop the conduction during t_{on} min.

The t_{on} min function cannot be disabled.

- Maximum conducting time (R_t and C_t inputs)

At the start of each conduction period the capacitor C_t is loaded by a constant current 1/2, where I is the current through resistor R_t ($I = 5/R_t$). When the voltage across C_t reaches + 5 V the conduction is stopped. The value of t_{on} max is thus given by the equation :

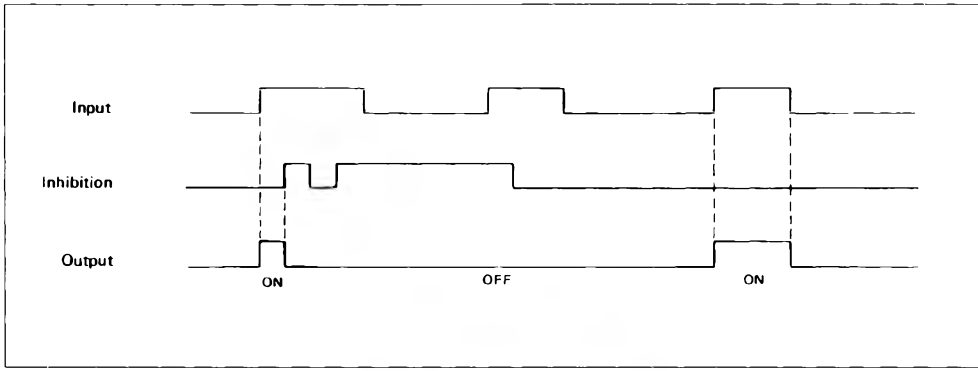
t_{on} max (s) = 2 x R_t (k) x C_t (nF)

If the t_{on} max function is not to be used, it is only necessary to replace capacitor C_t with a short-circuit.

- Time delay function

A constant time delay may be implemented between the rising edge of the control pulse and the begin-

Figure 5.

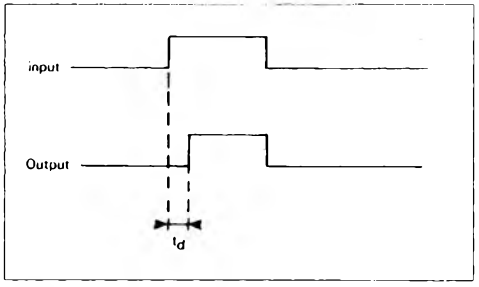


ning of the conduction pulse at the circuit output = (1 to 20 µs by using resistor R_D, t_d (µs) = 0.05 R_D (kΩ).

LOGIC PROCESSOR

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

Figure 6.



- No double pulsing within a period : the occurence of a defect is memorized until the end of the period.
- To allow the discharge of a snubber network, the minimum output pulse width is set at a given value t_{on} min.

OUTPUT STAGE : V^+, V–, I_{B1}, I_{B2}, INPUTS

- Introduction

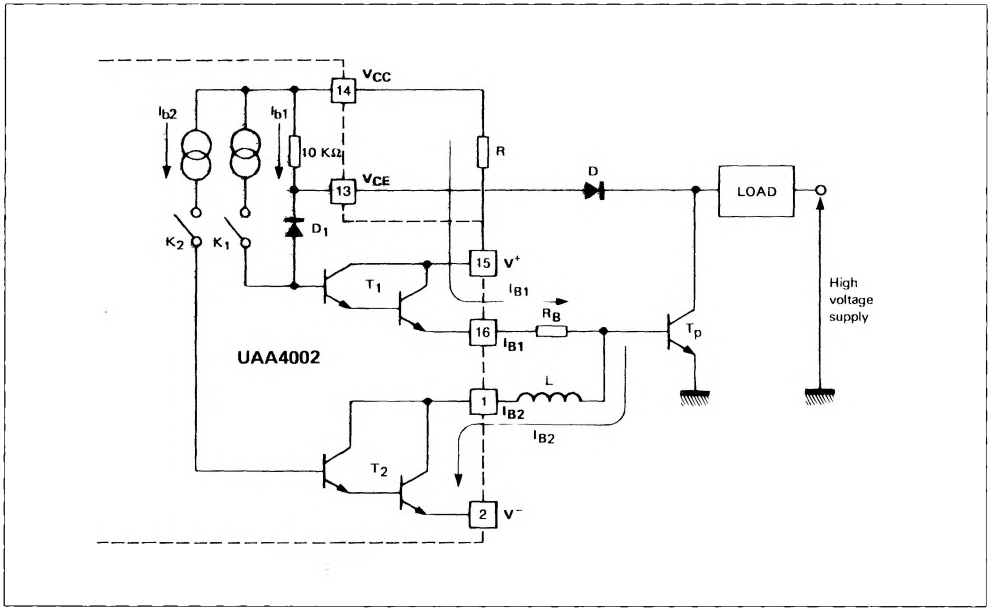
The highly sophisticated output stage of the UAA4002 offers high performance is terms of switching transistor control.

Its principal features are as follows :

- the switching transistor is direct driven
- the transistor remains in a quasi-saturated state, whence reduced storage time
- control power is limited to the strict minimum
- it is easy to use

This stage is in fact in two parts, a positive driver stage which turns on the transistor and a negative driver stage which turns off the transistor.

Figure 7.



- Power transistor conduction

The maximum value of the positive base current is determined by the limitation resistor R (I_{B1} 1 A). A regulation loop is used to keep T_p in a quasi-saturation mode : the more T_p becomes saturated, the more diode D will shunt an important part of the drive current I_{B1}, through diode D_1. R_B is a low value resistor (about 1) which helps to stabilize the regulation loop.

Voltage V_{CE} across transistor Q is :

V_{CE} (V) = V_{BE} (V) + R_B () I_{B1} (A)

If the required drive current is greater than 0.5 A, one external NPN transistor may be added.

In this case :

V_{CE} (V) = 2 V_{BE} (V) + R_B ().I_B (A)

- Turn-off switching of power transistors

The closing of contact K_2 (figure 10) causes Darlington T_2 to conduct. The negative supply voltage is applied to the base of transistor T_P and a high negative base current I_{B2} flows, permitting the rapid evacuation of charges stored in the base-emitter junction of transistor T_P.

A low-value inductor L may be required between the base of transistor T_P and the I_{B2} output of the UAA4002, so as to limit the gradient dI_{B2}/dt (see "The Power Transistor in its Environment" published by the Discrete Semiconductors Division of Thomson-CSF). In many cases, this inductor is not required.

The Darlington T_2 can carry a maximum current of 3 A. The corresponding saturation voltage is typically 3 V. Like the positive stage, this stage is designed for easy augmentation of the available output current by the addition of one or more external transistors.

- Typical inductive load waveforms

When conduction begins, the base current assumes a high value briefly and then reverts to zero. This base current spike permits rapid switching on of the power transistor. The base current value is then that required for quasi-saturation of the transistor. The base current curve is generally curved upwardy, due to the decreased gain of the power transistor with increased collector current.

Figure 8.

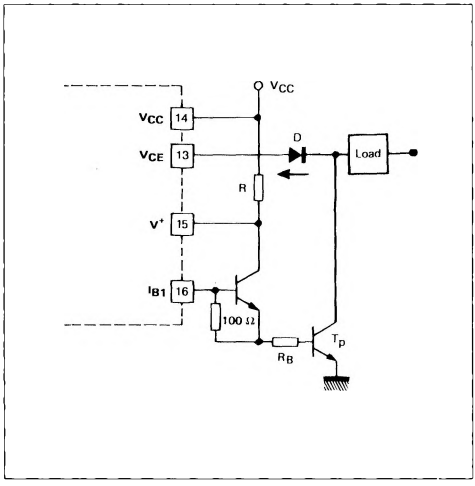
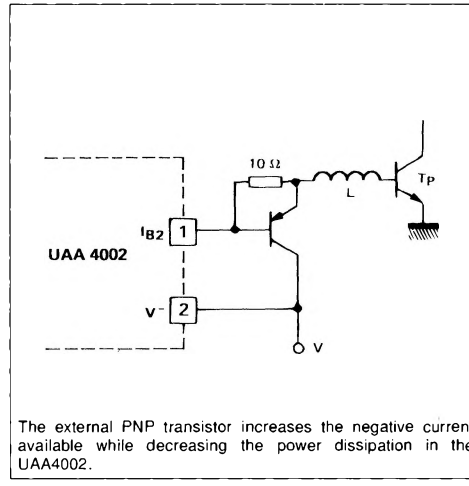
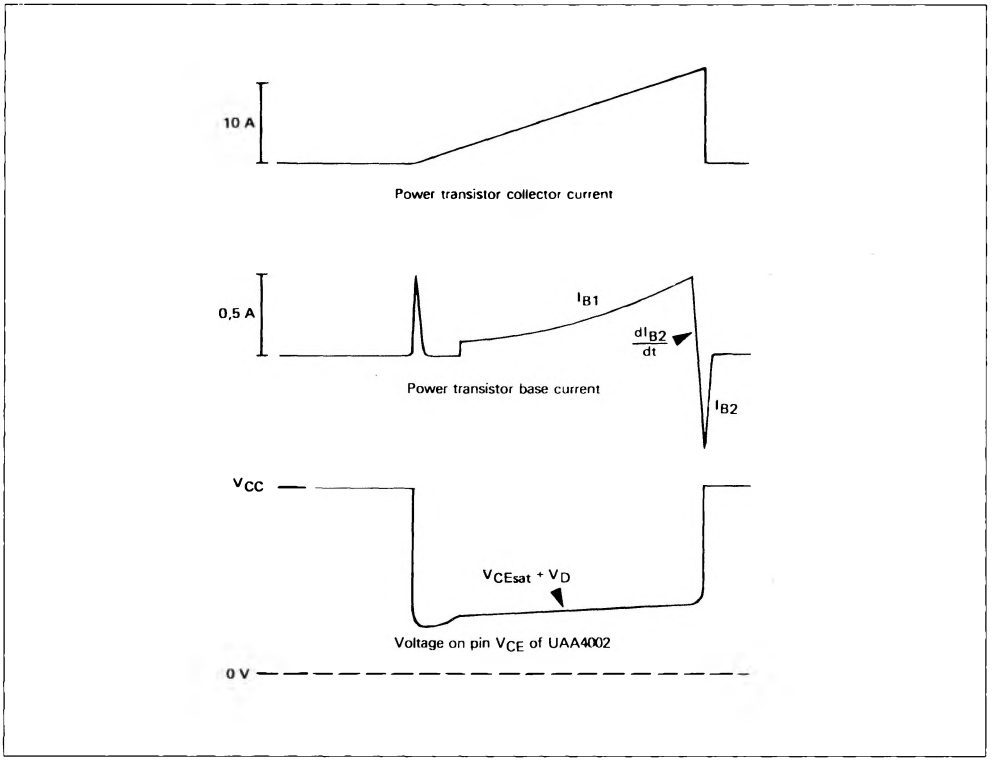


Figure 9.



The external PNP transistor increases the negative current available while decreasing the power dissipation in the UAA4002.

Figure 10.



CONTROL OF MOS POWER TRANSISTORS

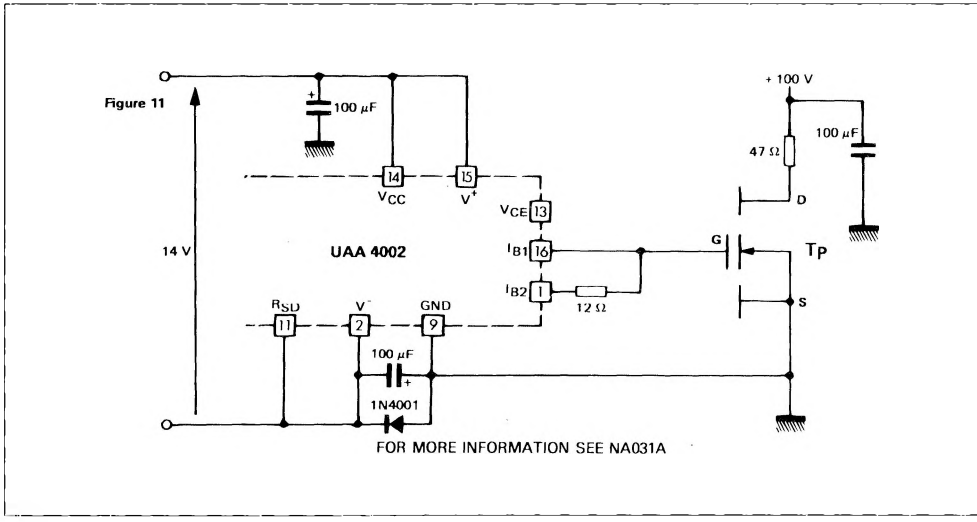
Ideally,MOS power transistors should be voltage-controlled. In practice, in order to benefit from the high speed typical of this type of transistor it is necessary to charge and discharge the spurious input capacitance at high speed, so that high currents flow. By virtue of the high current capability of its output stages, the UAA4002 is particularly suitable for controlling MOS power transistors.

The output of the positive stage is connected directly to the gate of the MOS transistor, to switch it into conduction very fast. The negative stage controls the turning off of the MOS transistor, by discharging the gate capacitance of the transistor. There is no need for a high negative supply voltage, and the arrangement described in the previous section is therefore used.

In this circuit the UAA4002 is used in a completely conventional manner, in "level" control mode.

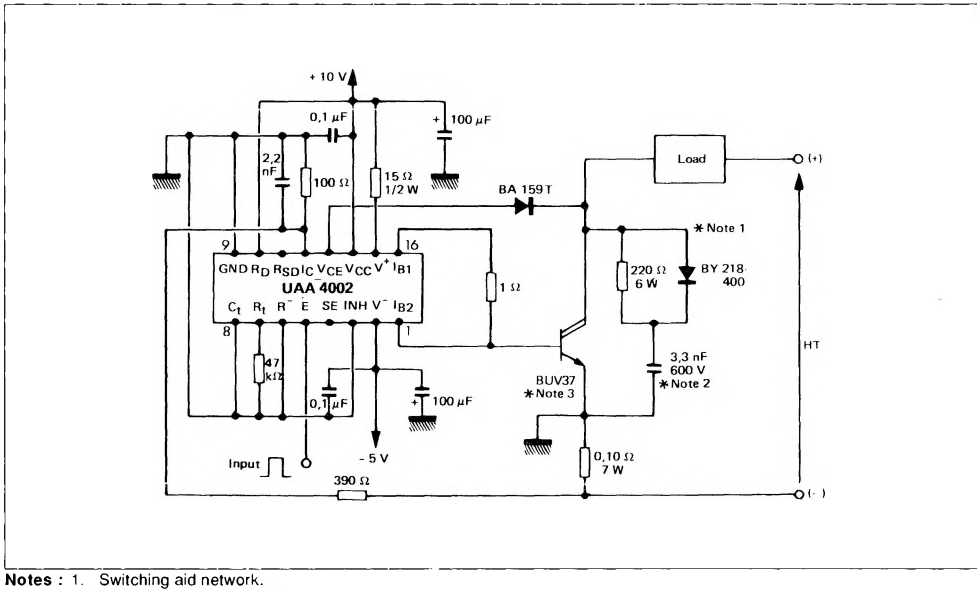
The time constant t_{on} min is set at 2.8 s, which is four times the time constant of the snubber network associated with the BUV37 transistor. The positive output stage of the UAA4002 is connected to the V_{CC} rail through a 15 resistor. The maximum base current is approximately 0.45 A. The collector current is measured using a 0.10 shunt, and is limited to 10 A. The BUV37 Darlington for which the specified value of I_{Csat} is 12 A, is thus operated with a considerable safety margin.

Figure 11.



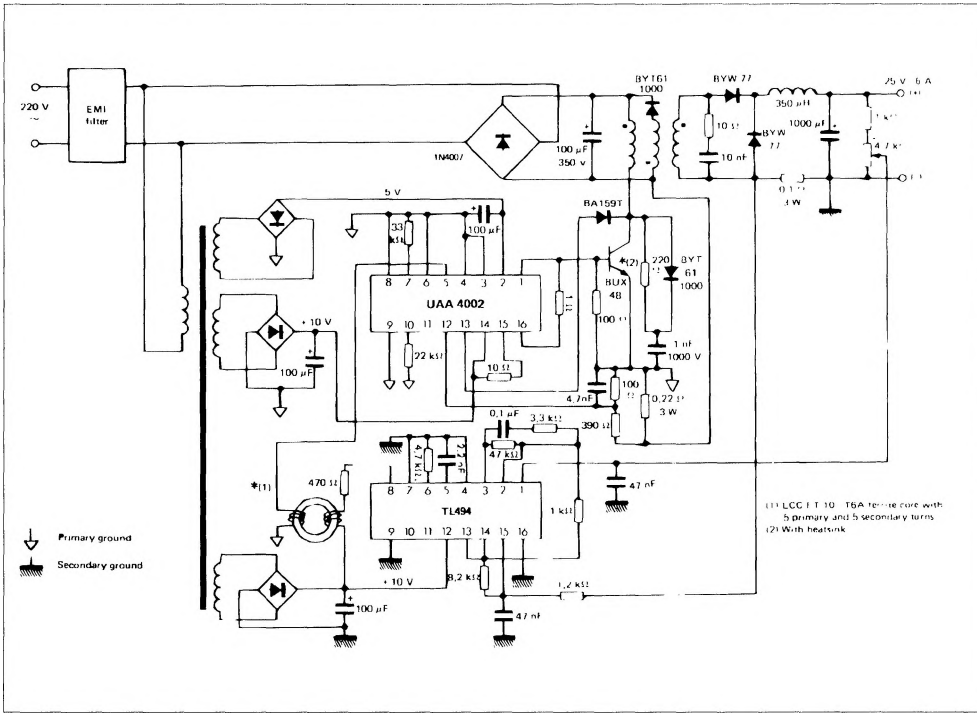
TYPICAL APPLICATIONS

Figure 12 : 8 A, 400 V switch.



Notes : 1. Switching aid network.
2. Polypropylene capacitor.
3. With heatsink, $R_{HT} < 3.5$ °/W.

Figure 13 : 150 W Forward Type Power Supply.



Performance

- Output voltage stability :
  For an input voltage varying from 190 to 245 V, the maximum relative variation in the output voltage is 0.7 % at nominal operating conditions.
  (V_{OUT} = 25 V, I_{OUT} = 6 A).
  For a variation in the load from 0 to 100 % the relative variation in the output voltage is 1.3 %.
  For a variation in the load from 10 to 100 % (I_{OUT} = 0.6 to 6 A), the relative variation in the output voltage is 0.4 %.
- Efficiency 80 % under nominal operating conditions.
- Behaviour on overload :
  The power supply is fully protected against overloads and short-circuits, the output current being limited to 7 A.

Figure 14 : Capacitor Type Half Bridge Symmetrical Converter.

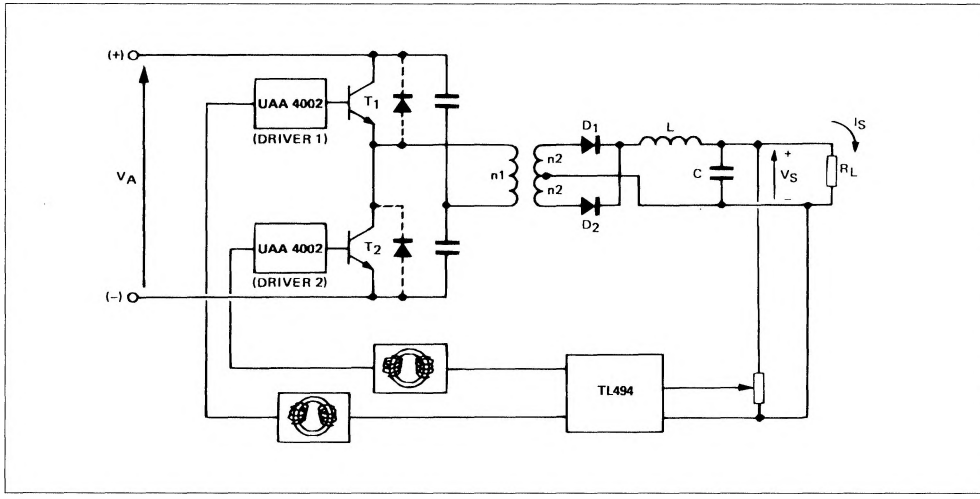


Figure 15 : 200 A, 700 V Switch.