Order this document
as AN479/D

MOTOROLA
SEMICONDUCTOR
APPLICATION NOTE

AN479

Universal Input Voltage Range Power Supply for High Resolution Monitors with Multi-sync Capability

By J. P. Bruniquel,
Integrated Circuits Application Lab.,
Motorola S.A., Toulouse

ABSTRACT

This Application Note describes an easy to build, high performance, low cost 100W FLYBACK power supply, able to work on any mains supply from 85 Vac to 265 Vac, from 40 Hz to 100 Hz. It is automatically synchronised on the horizontal scanning frequency for minimum screen interference on a multi-sync colour monitor, thanks to the versatile, high performance, low cost current mode controller MC44602P2, associated with the state of the art switchmode power transistor MJH18010.

INTRODUCTION

The MC44602 has been specifically designed to drive high voltage bipolar transistors. Its 1A source and 1.5A sink capability, with all the protection features associated with flyback power supplies, make it ideal for this kind of application.

New multi-sync high resolution colour monitors have horizontal frequencies in the range of 31.5 kHz to 85 kHz. The switchmode power supply associated with these high resolution colour monitors must be synchronized to the horizontal frequency in order to reduce any EMI/RFI effects visible on the screen. An important feature for an off line power supply is that it can be automatically adapted to any mains voltage without any hardware adaptation.

SPECIFICATION

Universal input voltage: 85 Vac to 265 Vac, 40 Hz to 100 Hz

Output voltages:

135V	0.4A
87V	0.2A
25V	0.8A
16V	0.3A
6.3V	0.8A

Output power: 100W

Short circuit protection on all outputs

Overload protection

Minimum efficiency: 80% at full load

Line regulation: $\leq \pm$ 1%

Load regulation: $\leq \pm$ 1%

External synchronisation: from 31.5 kHz to 85 kHz

Low overall cost.

MOTOROLA

TOPOLOGY AND MODE OF OPERATION CHOICE

For multi output voltages at 100W output power, the best choice is the SINGLE ENDED FLYBACK TOPOLOGY. The best price/performance ratio is offered by a combination of a high performance current mode controller MC44602 and a MJH18010 switching planar power transistor.

Depending on timebase frequency and mains voltage, the power supply works in either a discontinuous or a continuous current mode. Continuous current mode is for low mains voltage, and discontinuous current mode is for high mains voltage and low power. The continuous current mode at low mains voltage lowers the peak current (I Peak) on the transistor and as a consequence lowers the V_{ce} sat, the I_{b1} and the losses. At high mains voltage the discontinuous current mode allows lower switch-on losses and lower stress on the high voltage output diode. When the output diode has to switch current, its losses are higher (Trr).

The losses on the output diode depend on its current during conduction and current during switching. In discontinuous current mode there is no current in the diode at switch on. In continuous current mode there is always current in the diode at switch on and the Trr of the diode (switching losses) depends on this current. To accommodate a wide range of applications, the frequency of operation will be between 31.5 kHz and 85 kHz.

The MC44602 has a separate synchronisation input which resets the oscillator when a 5V positive pulse is applied. Since the oscillator of the MC44602 is working at twice the output frequency, the power supply will be synchronised at half the horizontal scanning frequency resulting in less disturbance on the screen with the synchronisation occurring only every two lines. Another advantage is for the power transistor which results in fewer switching losses, as it works at half the scanning frequency. Switching losses are directly related to the switching frequency, since they are the same for each cycle. The higher the frequency, the greater the losses.

A zener limits the input voltage to 4.7V on the sync. input. (See figure 1.) The synchronisation transformer is a toroidal bifilar core which receives the pulses from the time base of the monitor. The sync. pulse will have 5V amplitude and about 2 µS width. The main noise source is the high di/dt occurring at switch off. The power supply works at half the scanning frequency, so the impact of that disturbance is divided by two.

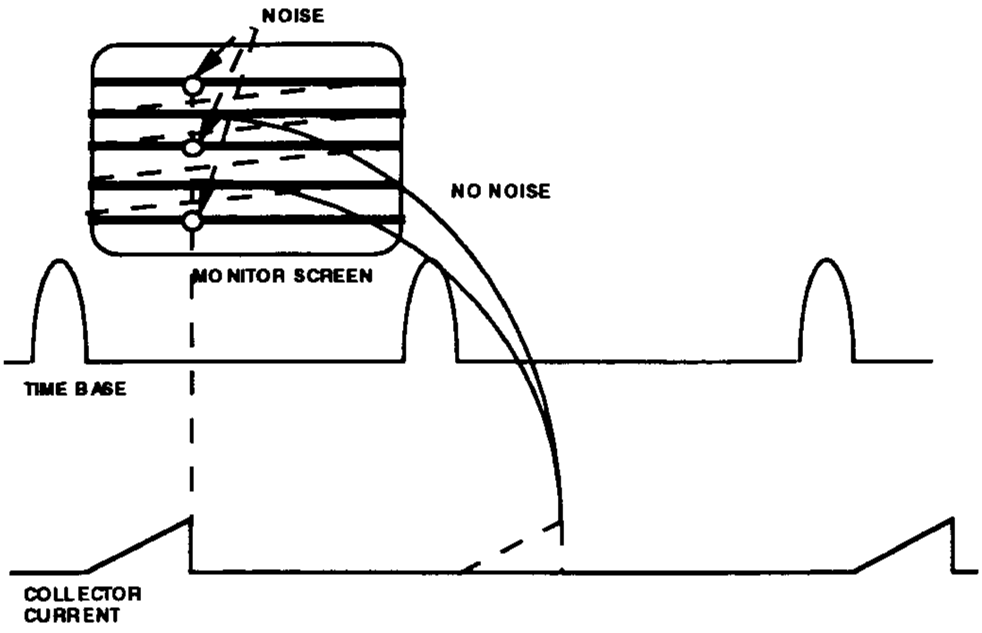


Figure 1 Switch off screen polution

TRANSFORMER DESIGN

Since the transformer plays one of the most important parts in the performance of a flyback power supply, due to coupling and leakage inductance, the transformer was designed around a SMT47 multislots former and a B3 GETV 53.18.18. ferrite core from THOMSON OREGA.

The feedback from the output voltage is magnetically realised by the auxiliary winding which performs good load, line and cross regulation, without the need for an optocoupler.

This auxiliary winding has three main functions (see MC44602 data sheet):

Self supply of the MC44602

Image of output voltage for regulation

Image of output voltage for overload detection.

Since the power supply will work from 85Vac to 265Vac, the minimum rectified voltage U is $85\sqrt{2}=120V$.

To provide a safety margin in worst case conditions (low mains-high power), let us choose a minimum DC voltage U of 90V.

The maximum DC voltage is $265\sqrt{2}=375V$.

Assuming an 80% efficiency with an output power of 100 W, the input power P_{in} is 100/0.8=125W.

The maximum primary current occurs at minimum voltage U and minimum switching frequency Fs which is 31.5 kHz/2 = 15.25 kHz.

The transformer must be calculated for 15 kHz minimum frequency.

Let us choose a maximum duty cycle of D= 0.4 for a minimum mains voltage, a minimum switching frequency and maximum power. Then I_p, the peak current in the transistor, becomes:

$$I_p = 2P_{in}/U * D = 2*125/90*0.4 = 7A$$

$$L_p = 2P_{in}/Ip^2 * Fs = 2*125/49*15*10^3 = 340\mu H$$

A ferrite material with AL=460 nH/T can be chosen. The number of primary turns is:

$$Np = \sqrt{L_p/AL} = \sqrt{340*10^{-6}/460*10^{-9}} = 27 \text{ Turns}$$

TRANSFORMER CONSTRUCTION

The technique used is the multi slot developed and widely used by OREGA THOMSON. Figures 2 and 3 depict the way to couple the different windings in order to achieve a high coupling; this ensures an acceptable magnetic feedback signal and a low leakage inductance.

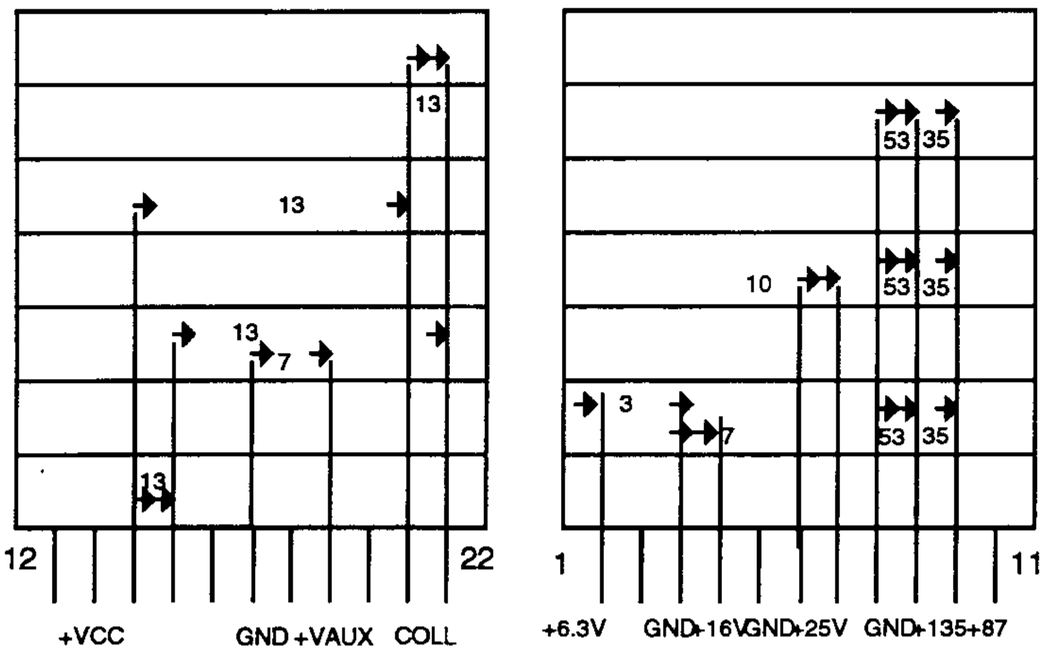


Figure 2 Multi slot winding

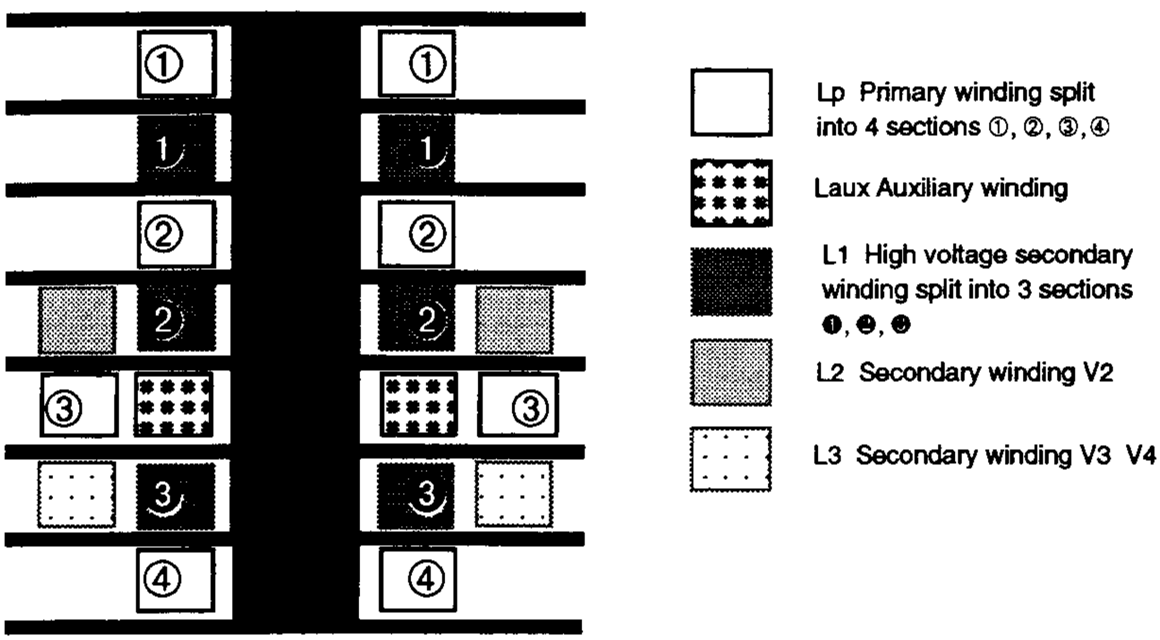


Figure 3 Physical winding position

For multislot construction we chose 2*13 Turns =26 Turns

Ns 135V	=Np*(1-D)*(Vs+Vf)/Vin min *D =26*0.6*136/100*0.4 = 53 turns =2.5V/Turn
Np=26T	0.5mm diameter
Ns 135V=53T	0.315mm diameter
Ns 87V=35T	0.5mm diameter
Ns 25V=10T	0.5mm diameter
Ns 16V= 7T	0.5mm diameter
Ns6.3V= 3T	0.5mm diameter
N V_{aux} =7T	0.5mm diameter

All wires are enamelled grade 2

Leakage inductance < 2%

SEMICONDUCTOR SELECTION

THE CONTROLLER

The MC44602 high performance, fixed frequency, current mode controller is the heart of the flyback power supply.

This circuit, specially designed for off-line and high voltage DC-DC converter applications with bipolar transistors, offers:

- Separate high current source and sink outputs
- Unique overload and short circuit protection
- Thermal protection
- Oscillator with sync input
- Current mode operation to 500 kHz output switching frequency
- Output dead time adjustment
- Automatic feed-forward compensation
- Latching PWM for cycle by cycle current limiting
- Input and reference undervoltage lockouts with hysteresis
- Low start-up and operating current

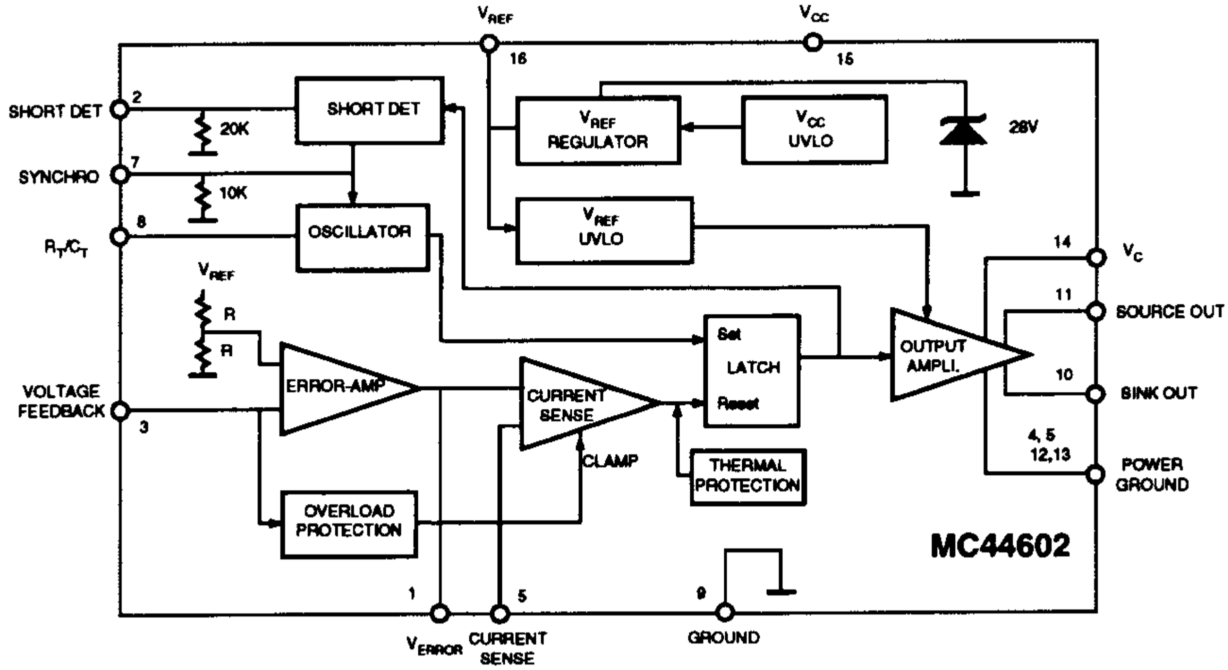


Figure 4 Simplified block diagram

THE SWITCHING TRANSISTOR

With a peak current of 7A, the state-of-the-art planar switchmode bipolar power transistor MJH18010 is a good choice.

On control: its power gain of 10 at 7A needs an I_b current of only 0.7A.

With I_{b1} = 0.7A, the base resistor R6= $(V_{aux}-V_{sat}$ MC44602 $-V_Z - V_{be\ on} - V_{pin5})/I_{b1}$.

$V_{pin5}=R9 * I_{peak\ max}$.

R6 = (16V-2V-4.7V-0.7v-1.5V)/0.7A =10Ω

Off control: for reverse base current I_{b2}, a zener limits the reverse voltage to 4.7V, and the 2.2 µH L2 inductor limits the di/dt of reverse current to avoid I_c current crowding during T_{off}.

A clamping circuit is added on the collector of the power transistor to limit the peak voltage and stress during the RBSOA.

The maximum collector voltage is: $V_{coll} = U+(V_{out}/N)$

N=Np/Ns =0.5

For V_{out} = 135V, V_{coll}= 375+(135/0.5) = 645V

The snubbing capacitor of 330pF limits the dv/dt of the transistor at switch off; see ANE424 and AN1080.

THE OUTPUT DIODES

Since the power supply can work in continuous current mode, the output diodes need to be ULTRAFAST diodes thanks to their low TRR.

For 135V output, maximum reverse voltage is V_{out} +(max $V_{CC/n}$) n=Ns/Np

135+(375/0.5)=885V + ripple. The diode is a MUR4100E.

For 87V output, maximum reverse voltage is 87+(375/0.75)=587V. The diode is a MUR460.

For 25V out the diode is a MUR420.

For 16V out the diode is a 1N4934.

For 6.3V the diode is a MUR415.

SCHEMATIC DIAGRAM

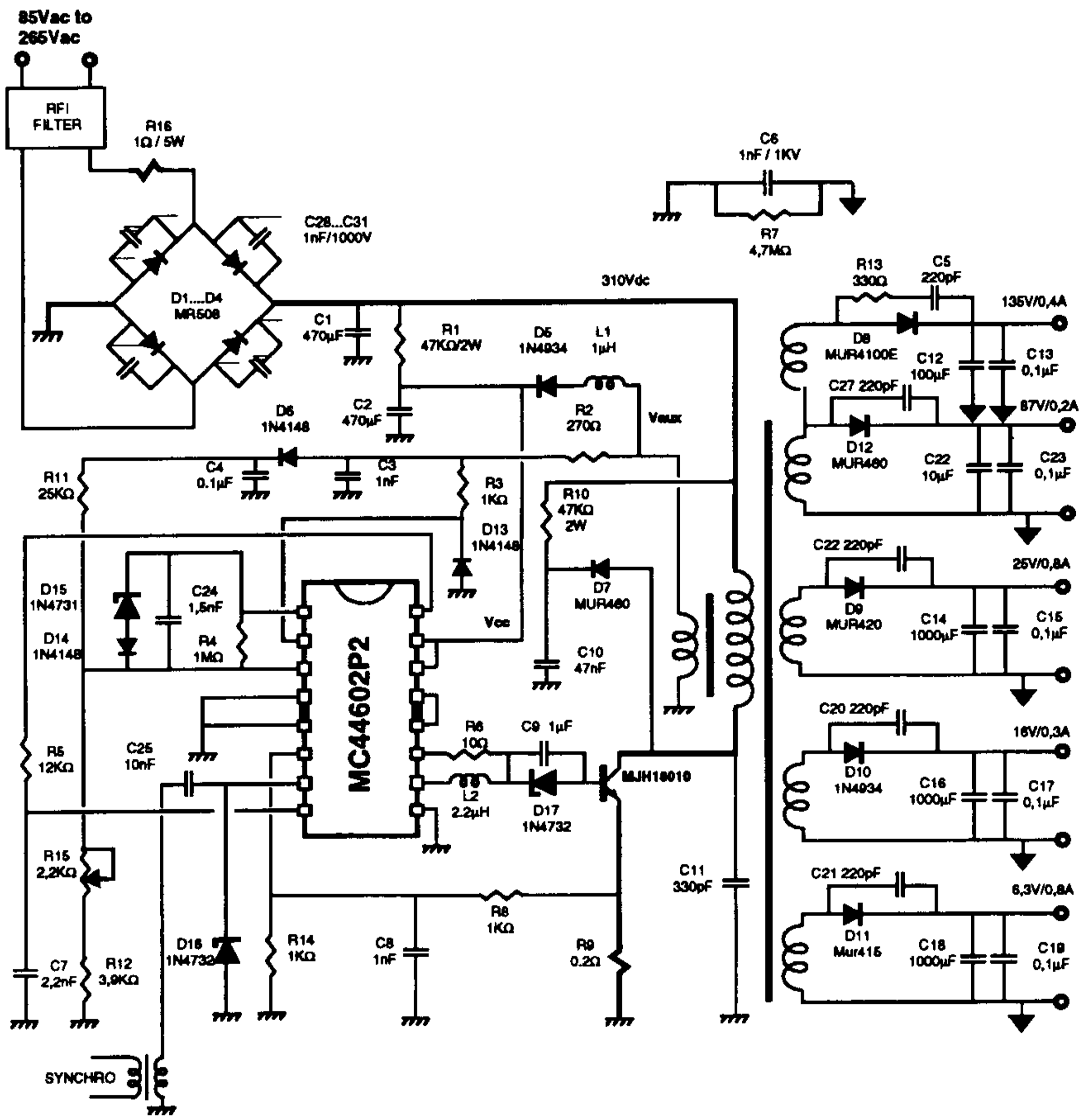


Figure 5 100W power supply schematic

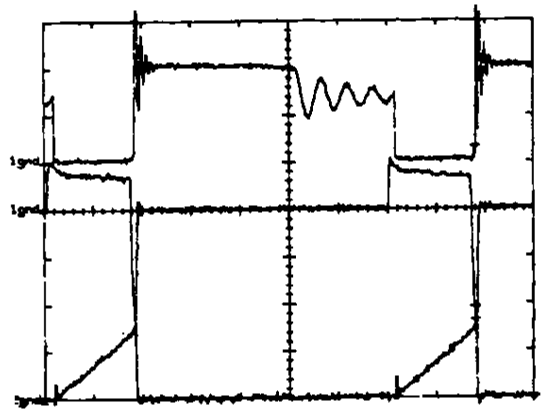
PERFORMANCE

Test	Conditions	Results 31.5 KHz to 85 KHz
Line Reg	V_{in} = 85Vac to 265Vac	
135V	I_{out} = 0.4A	Δ= 0.3V or +/-0.15%
87V	I_{out} = 0.2A	Δ= 0.1V or +/- 0.1%
25V	I_{out} = 0.8A	Δ= 0.15V or +/-0.3%
16V	I_{out} = 0.3A	Δ= 0V
6.3V	I_{out} = 0.8A	Δ = 0V
Load Reg	V_{in} = 110Vac	
	V_{in} = 220Vac	
135V	I_{out} = 0.2A to 0.4A	Δ= 2V or +/- 0.75%
Ripple	I_{out} = 0.4A	
135 V	V_{in} = 85Vac	1V (31 KHz) 0.4V(85 KHz)
	V_{in} = 85Vac	0.3V (50 Hz)
	V_{in} = 265Vac	1V (31 KHz) 0.3V (85 KHz)
	V_{in} = 265Vac	0V (50 Hz)
Efficiency	V_{in} = 110Vac/220Vac P_{out} = 100W	80%
Stand-by Mode		
P input	V_{in} = 90Vac, P_{out} = 0W	2.5 W
P input	V_{in} = 220Vac, P_{out} = 0W	5.5 W
Output short circuit	Safe on all outputs	

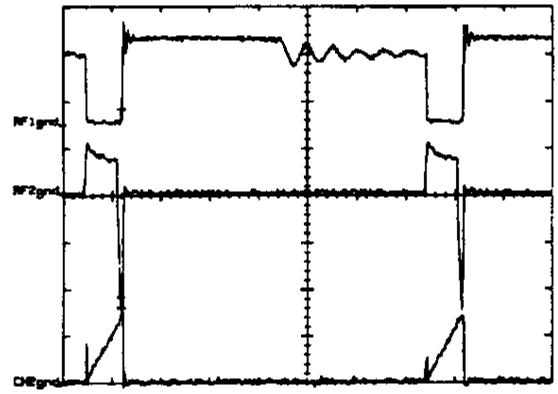
LIST OF SEMICONDUCTORS

Integrated Circuit	MC44602P2	1
Transistor	MJH18010	1
Diodes	MR508	4
	1N4934	2
	1N4732	2
	MUR460	2
	MUR4100E	1
	MUR420	2
	MUR415	1
	1N4148	3
	1N4731	1

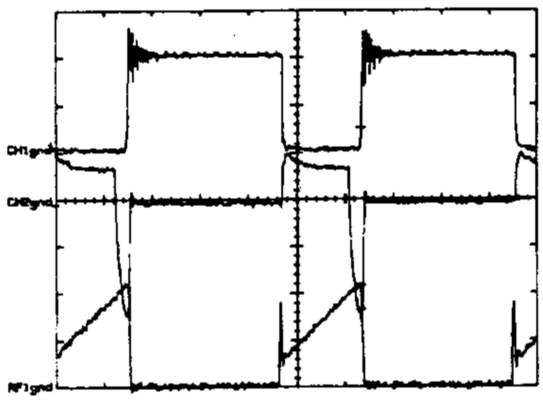
OSCILLOGRAMS



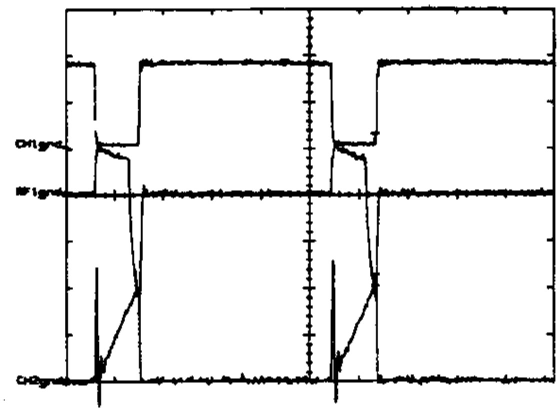
Vin 110Vac F=31.5kHz Vcc=100V/Div Ic=5A/Div Ib=1A/Div



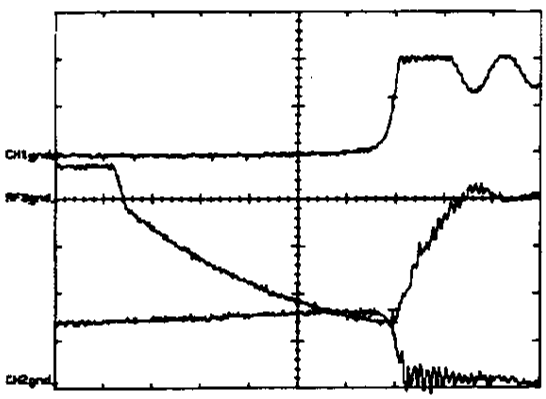
Vin 220Vac F=31.5kHz Vcc=200V/Div Ic=5A/Div Ib=1A/Div



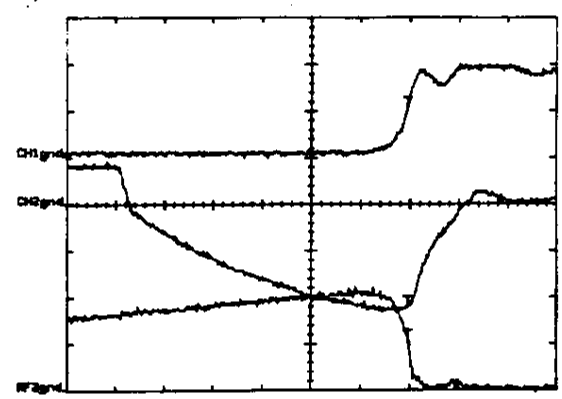
Vin 110V F=85kHz Vcc=100V/Div Ic=5A/Div Ib=1A/Div



Vin 220Vac F=85kHz Vcc=200V/Div Ic=5A/Div Ib=1A/Div



Vin 220Vac F=31.5kHz Vcc=200V/Div Ic=2A/Div Ib=1A/Div



Vin 220Vac F=85kHz Vcc=200V/Div Ic=2A/Div Ib=1A/Div

Figure 6 Typical results obtained

CONCLUSION

This paper demonstrates that the use of the new current mode controller is an easy way to realise a high performance, low cost, universal input, voltage range power supply with multisync capability.

The regulation performance can be improved at extra cost by using an optocoupler and a TL431 voltage reference in the feedback loop.

This power supply can be adapted to other output voltages by changing the transformer.

REFERENCES

AN1080/D Application note

MC44602 Data sheet

MJH18010 Data sheet

ANE424/D Application note

Literature Distribution Centres:

EUROPE: Motorola Ltd., European Literature Centre, 88 Tanners Drive, Blakelands, Milton Keynes, MK14 5BP, England.
ASIA PACIFIC: Motorola Semiconductors (H.K.) Ltd., Silicon Harbour Center, No. 2, Dai King Street, Tai Po Industrial Estate, Tai Po, N.T., Hong Kong.
JAPAN: Nippon Motorola Ltd., 4-32-1, Nishi-Gotanda, Shinagawa-ku, Tokyo 141, Japan.
USA: Motorola Literature Distribution, P.O. Box 20912, Phoenix, Arizona 85036.

MOTOROLA

AN479/D

JIT PRINTED IN THE USA 1993 MPS