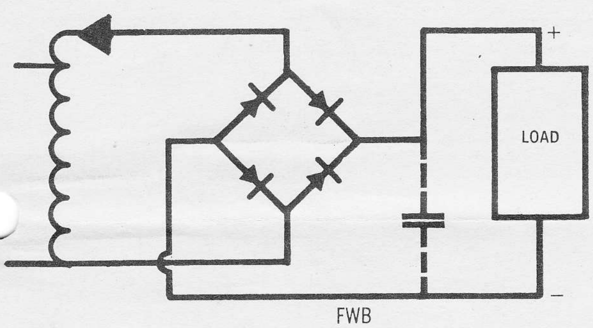
Electric Auto Association NEWS

MARCH 1986 VOL. XVIII NO. 3

HOW DO I CHARGE MY BATTERIES WHEN I'M TOOLING IN THE TOOLIES

You are seldom far from some kind of power, farmhouse, country store, service station, & etc. If you carry a variac, 50 or 100 Amp @ 220 Volts. Four diodes, 100 Amp. @ 300 Volts, formed into a diode bridge with heat sinks. You can charge almost any battery system, from any ac power source (110 to 240 Volts).



CAUTION! DANGER HIGH VOLTAGE!!

A Variac is a variable autotransformer which means charging leads are directly connected to the power line, NO ISOLATION. You should isolate your batteries from the body of vehicle and ground body before connecting charger.

IMPORTANT NOTICE

EXPO '86

EV MARKETPLACE

AND CALL NOW!!

"THE ROLE OF ELECTRIC VEHICLES IN THE NATION'S ENERGY FUTURE"

A recent government publication, written by J.G.Asbury, J.G.Seay and W.J.Walsh, all of Argonne National Laboratories (ANL). The 28-page booklet is designated ANL/SPG-26. The report examines the transportation fuel outlook, the nation's dependence on foreign oil and the future cost of domestic substitutes for petroleum, including oil from shale and methanol from coal. Then an economic comparison of the EV with the internal combustion engine vehicle (ICEV) is presented. Battery break-even cost and performance requirements are established, along with prospects for meeting them through candidate battery technologies. The following quotes from the conclusions: "Vehicles range was found to be the most important design consideration affecting the cost and performance requirements of the electric battery. Present battery technology is adequate to achieve cost-competitive EV's with a 50-mile range. Moreover, battery technology appears to be on the threshold of enabling economical vechicles with a 100-150 mile range. Continued development of sodium/sulphur, lithium-metal/sulfide, zinc-bromine, zinc/chlorine, iron/air and serveral other battery technologies may enable cost-competitive EV's with a 100-150 mile range during the 1990's. On the other hand, a major breakthrough in battery technology is required for EV's with a 250-mile range. In particular, substantial reductions in battery cost ($/KWH) are required, regardless of the improvement in specific energy. The EV represents an important long-run transportation alternative for the U.S. Compared with the enormous investments in new conversion facilities required for synthetic fuels, the effects of EV's on the nation's electrical supply system will be modest. Nevertheless, the market and technical risk associated with their development call for continued government support." Amen.

From Ed Campbell's AET Newsletter

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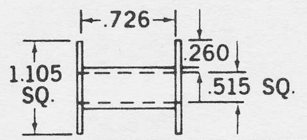
Cont'd from Feb.

FIGURE 5.

BOBBIN WOUND COIL DESIGN DATA - SW2



COIL FORM PERIMETER: 2.30 IN.
COIL MEAN TURN: 3.05 IN.
WIRE WEIGHT: SOLID = .088 # STD'D = .063#

AWG	MAX DIA	CIRC. MILS	TURNS/LAYER	NO. LAYERS	TOTAL TURNS	DCR
30H	.0119	100	60	18	1080	28.3
29H	.0133	128	53	16	848	17.4
28H	.0147	159	48	14	672	11.0
27H	.0164	202	43	13	559	7.25
26H	.0182	253	38	11	418	4.27
25H	.0203	320	34	10	340	2.75
24S	.0217	404	32	9	288	1.83
23S	.0243	511	28	8	224	1.12
22S	.0270	640	25	7	175	.697
21S	.0303	812	22	7	154	.497
20S	.0339	1024	20	6	120	.304
19S	.0379	1289	18	5	90	.178
18S	.0424	1624	16	5	80	.129
17S	.0475	2052	14	4	56	.070
16S	.0531	2581	12	4	48	.049
5 × 30	.029	500	24	7	168	.871
7 × 30	.0342	700	20	6	120	.445
10 × 30	.0408	1000	16	5	80	.208
15 × 30	.0498	1500	13	4	52	.089

2. Parallel wires used for secondary 1 to minimize wire size.
3. Secondaries are bifilar wound where practical for good intersecondary coupling.

Design Verification

Best practice is to estimate the transformer temperature rise and then test in the application. To estimate temperature rise, determine the total transformer losses, then use the equation in step 14.

13. Core loss was set in step 4, therefore copper losses must be estimated at this point. $P_{cu} = \Sigma I_r^2 R_{AC}$

Winding	I_r Amps	R_{DC} Ohms	R_{AC} Ohms	$I_r^2 R_{AC}$ Watts
Primary	1.100	0.240	0.520	0.63
Catch	0.345	0.470	0.630	0.06
S1	6.740	0.004	0.012	0.55
S2	0.670	0.008	0.024	0.01
S3	2.020	0.016	0.048	0.020
S4	2.020	0.016	0.048	0.200
S5	0.404	0.098	0.132	0.02
Total P_{cu} =				1.67

RMS currents from step 11
DC resistance estimated from Figure 5.
AC resistance estimated using curves adapted from reference 1.

14. Estimate temperature rise:

$$T = [43.7(P_{FE}/P_{cu}) + 76.3]\, P_{cu}/A_s^{0.882}$$

$$= [43.7\,(0.93/1.67) + 76.3]\,(1.67/5.73^{0.882} = 36°$$

P_{cu} from step 13, P_{FE} and A_S from Figure 3.

NOTE: In step 5, more than minimum turns were used; therefore, the actual core loss will be less than 0.93 watts.

Finally the transformer is tested in the application to complete the verification step. The temperature rise of this design measured 34°C. Output voltages are shown in Figure 6.

Figure 6. Continuous Mode Flyback Transformer - 100kHz

Auxiliary Output Regulation
Input: 120VDC

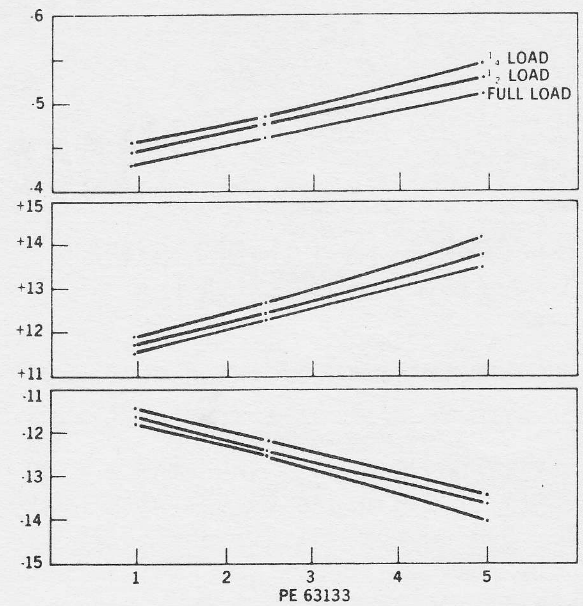
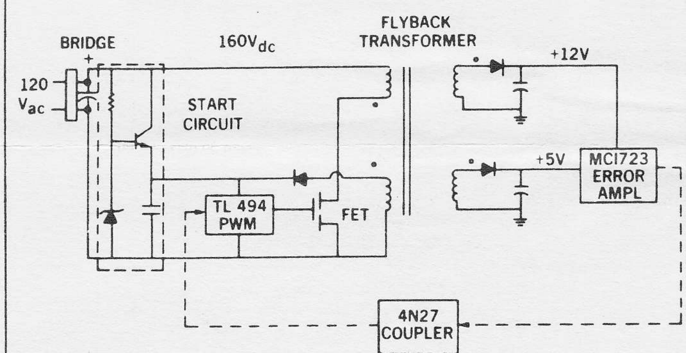


Figure 7. Regulator Block Diagram



Circuit Design

The goal of most low power flyback designs is for reduced parts count (or size) and reduced cost. This 60W 100kHz switcher is no exception. At 100kHz, the transformer size and cost design are reduced by about 30% over a 20kHz design and it still performs very well as shown in the previous discussion. Also at 100kHz, a FET can be driven directly from logic circuits (100 to 200mA) and still switch very efficiently. This eliminates the need for drive interface circuits. The output caps used here are about 50% smaller and they cost less as well. Finally, the relatively new three chip control system is used here. It replaces an expensive and performance limited drive transformer with a lower cost opto coupler. The functional block diagram of this design is shown in Figure 7. The FET is the control element for the flyback transformer and is directly driven from the 494 linear IC circuit. A rather standard off line starter circuit is used to initially power the control circuit and this is also lower in cost than the filament transformer supply which is

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A 100kHz FET Switcher

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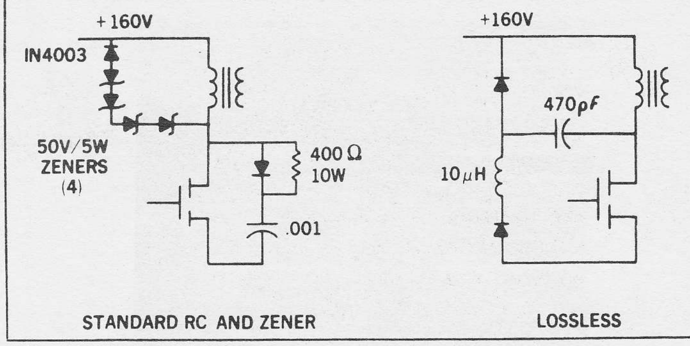
often used to power a single chip system. The design procedure followed here was:

1. Design and test the power stage.
2. Add and stabilize the control loop.
3. Change from DC to AC power.

A schematic of the regulator is shown in Figure 8. The original transformer design is shown here as a point of reference. It used a slightly larger EC core but had an ineffective clamp winding. To contain the switching transient from this transformer, both snubber circuits shown in Figure 9 were tried. The first worked but dissipated about 5W. The loss-less snubber slowed turn off and lowered the ringing frequency but did not reduce the peak transients. Even with higher values of L and C this snubber was not able to contain the switching transients to less than 400V. However, when the Pulse Engineering transformer was substituted, clamping was so effective that the zeners and snubber were removed and replaced by a small RC network which dissipates about 1 watt and is used only to reduce ringing. The FET waveforms obtained with this final configuration are shown in Figure 10. The exceptional switching speed of the FET can be verified here (less than 50ns) and ringing on the current waveform is due to the layout which includes a current sense loop and noise pickup on the scope probe.

Figure 9. Snubber Circuits



The input cap does not reduce in size like the outputs because it is needed for energy storage which still occurs at 60Hz. Noise filters used here include a toroid from PE and the economical 41GS series of tantalum caps from M/E. The 12V output rectifiers were Motorola's new MR2400F fast recovery button rectifiers which are housed in a TO-220 package. They were ideally suited to this relatively high current (10-15A peak) application because the correct amount of heat sinking was easily attained by simply bolting a fin to the tab.

Figure 8. 100kHz FET Regulator

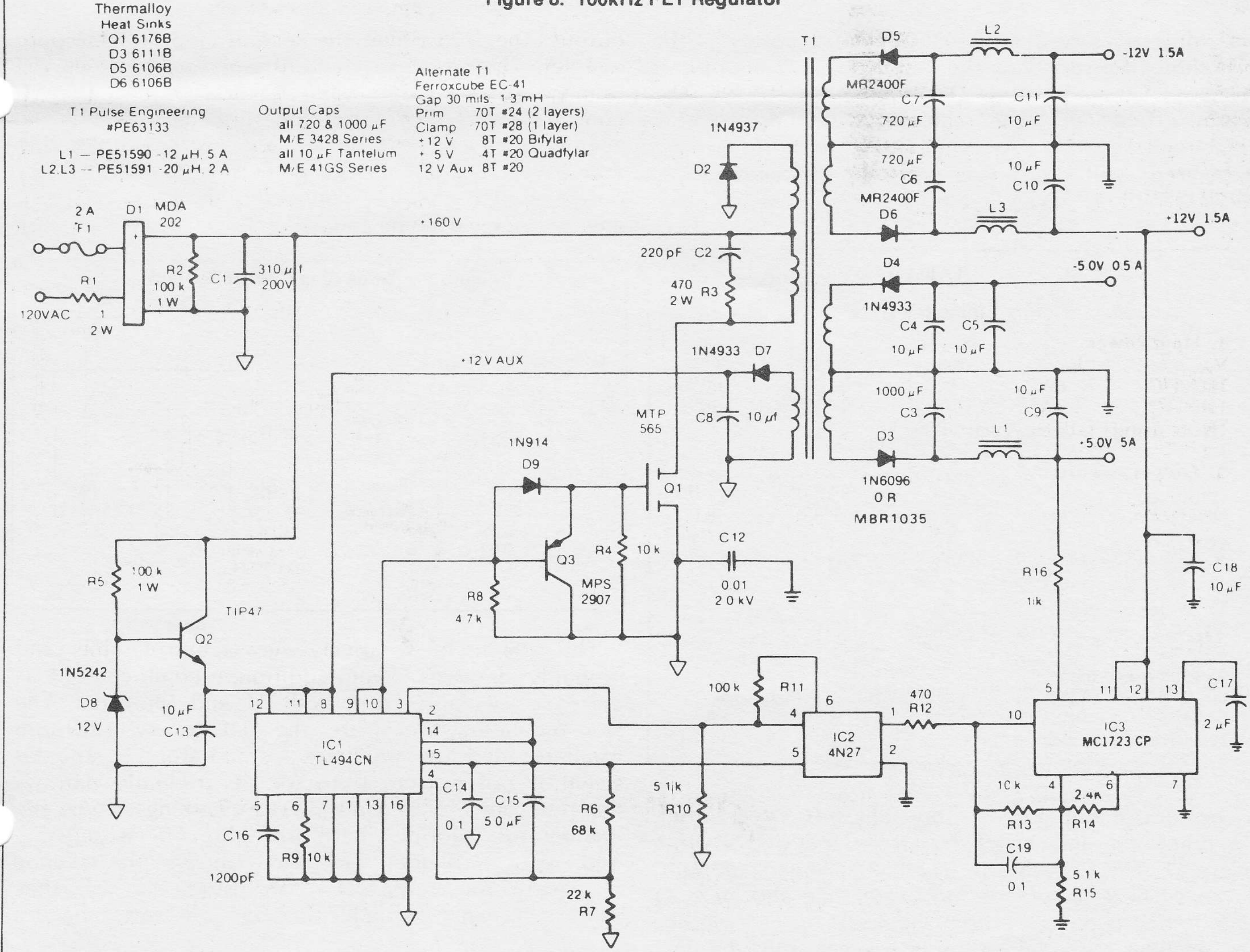
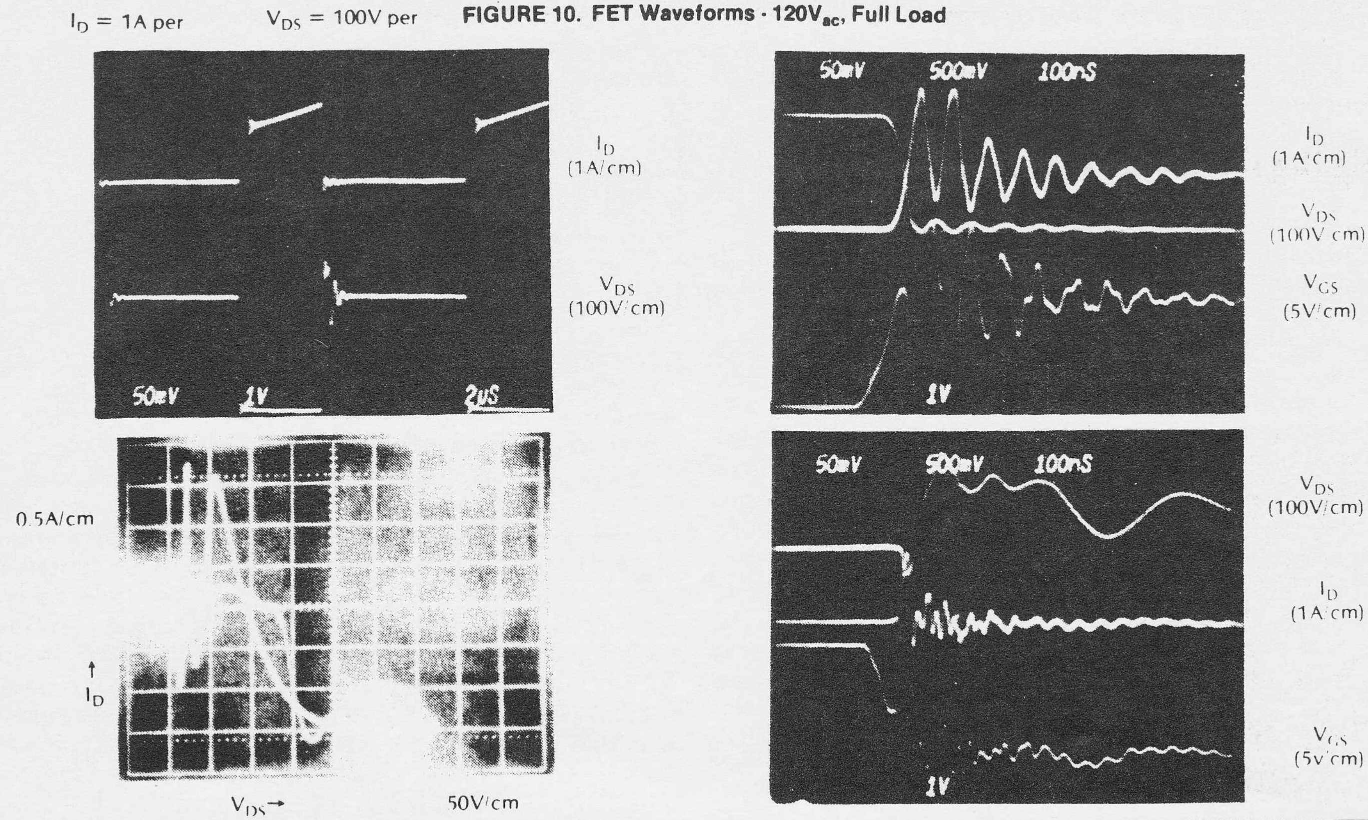


FIGURE 10. FET Waveforms - 120V$_{ac}$, Full Load



And Motorola's new MBR1035 TO220 Schottky is the best choice for rectifying the 5V output. It is about half the cost of the equivalent DO-4 version, a IN6095. The overall efficiency of this regulator (including the control circuits) is 75%. As usual, most of the losses are associated with the power handling components as noted in Table 1.

TABLE 1

Efficiency Data

1. Input Power

V_{IN}	I_{IN}	P_{PRMS}	P_A	PF
160VDC	.6A	96	96	100%
120VAC	1.4A	170	95*	56%

*Note using Clark-Hess wattmeter.

2. Output Power

Winding	15.0	-5.0	+12.0	-12.0
Load (ohms)	1.0	10.0	8.0	8.0
Voltage	5.1	5.1	13.2	13.3
Power	2.5	2.6	21.5	22.0

3. Efficiency

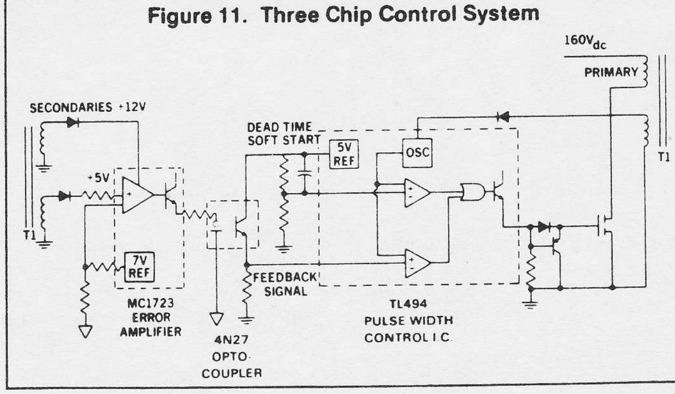
Eff. = P_o / P_{in} = 72W / 95W = 75%

4. Estimated Losses

FET	4W	Fast Recovery (both)	8W
Schottky	4W	Misc.	5W
Transformer	2W		

The control loop contains three chips as noted earlier. The functional diagram of this arrangement is shown in Figure 11. The first chip is an MC1723 linear regulator. It is used here to provide a 5V reference and an error amplifier. It is powered from the +12V output winding and receives feedback or control signal from the +5V output. The 1723 drives the second chip, a 4N27 opto coupler. The coupler maintains isolation between the primary and secondary windings and couples the DC control signal to the input of the third chip, a TL494. The 494 performs a fixed frequency pulse with width modulator (PWM) function and is used to directly drive the FET power switch which is connected to the primary or energy storage winding.

Figure 11. Three Chip Control System



The 494 is a relatively new control chip and probably deserves some additional comments. It is currently available from both TI and Motorola. The key regulating blocs are the 0.0 to 3V sawtooth oscillator and the feedback comparator. As the FB signal is raised from 0 to 3V, it gradually narrows the on time of output pulse coming from the comparator. During start up, the FB is missing and resistor divider network controls the second or dead time comparator to insure that on time cannot exceed 45%. This and the soft start capacitor

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A 100kHz FET Switcher

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prevents transformer saturation problems during start up. The 494 also features parallelable uncommitted output transistors which source about 500mA to the FET gate. Pull down of the gate voltage is accomplished as shown in Figure 11 with the addition of a low cost TO-92 PNP transistor. In this design, the 494 is started off line with the addition of a 200V transistor and 12V zener as shown in Figure 8. It ultimately (at normal line voltage) runs off the 12V auxillary winding which back biases this transistor. Because it and the FET gate draw so little current from the line, about 20mA, undervoltage inhibiting common to bypolar designs was not required here and this circuit becomes functional and runs safely when the input reaches 40V A.C.

Cost and Performance

The parts cost of this design is essentially the same as a similar bipolar design.* This switcher totaled $36.63 (versus $36.99) but does not include a relatively high priced ($6.63) FET switch. It is anticipated that within one or possibly two years, the FET price will be about half its present value and at that point in time, FET designs in general will be at least 10% lower in cost than the lower frequency bipolar designs. Prices of the individual components used in this design are shown in Table II. The high frequency (100kHz) FET designs like this one offer system savings over 20kHz bipolar designs in three areas:

1. Transformer size shrinks by about 30%
2. Output capacitors shrink by about 50% (input caps remain the same size and cost)
3. Interface circuits are reduced or eliminated because the FET is easier to drive.

And they turn out to be a little easier to design because of item 3 above. However, there are still the normal amount of precautions required in designing snubbers and clamps and in stabilizing the loop. And as most designers realize, the production cost of this design should and could easily be in the $25 to $30 range rather than $37. There was an attempt to keep the number of parts and cost down in this design. But further reductions are always possible such as a lower cost noise filter and control circuit.

*Reference "A 60 Watt Switcher", Electronics, Feb 80.

The performance of this 100KHz switcher is similar to most others. It is relatively easy to keep output ripple, both 60 and 100kHz, below 100mV on all outputs. (See Table III). Line regulation here was terrific (less than 0.1%) but load reg (2%) could have been better. Normally tight layouts and higher loop gain can get this down to 0.1 to 0.5% as well. Efficiency (75%) and cross regulation (±10%) were discussed earlier and are also similar to other multiple output switcher designs. To facilitate construction of this or a similar design, the parts layout and foil side of the PC board are shown in Figures 12 and 13.

TABLE II
100kHz FET Switcher
Parts List (1K Quantity, April 1981)

Semiconductors (Motorola)			
Transistors	MTP565	400V, 5A	$ 6.63
	Misc.		.45
Rectifiers	MBR1035	10A, 35V	1.44
	MR2400F(2)	24A, 50V	1.80
	MDA202	1A, 200V	.80
	Misc.		.50
IC's	TL494	SM Control	2.00
	4N27	Coupler	.42
	MC1723	Regulator	.26
Subtotal			$14.30
Magnetics (Pulse Engineering)			
Transformer	PE63133	60W	$6.00
Filter	PE51590	12μH, 5A	1.00
Filter	PE51591(2)	20μH, 2A	2.00
Subtotal			$9.00
Capacitors (Mepco/Electra)			
Input	3050 Series	310μ, 200V	$1.51
Output	3428 Series(2)	720μ, 20V	2.62
	3428 Series	1000μ, 10V	1.31
	41GS Series(6)	10μ, 20V	3.42
SUBTOTAL			$8.86
Miscellaneous			
Heat Sinks (Thermalloy)			$ 1.53
Resistors			.82
Capacitors			2.12
Subtotal			$4.47
Total Parts			**$36.63**

TABLE III
Output Data

1. Ripple Voltages (120VAC, Full Load)				
Winding	+5	−5	+12	−12
100K Ripple (PP)	60mV	300mV	70mV	50mV
60Hz Ripple (PP)	20mV	50mV	70mV	60mV
Noise Spikes (PP)	2V	2V	2V	2V
2. +5V Regulation				
Line	100VAC	100VAC	130VAC	130VAC
Load	Full	Half*	Full	Half*
Voltage	5.10	5.21	5.10	5.21

*Note: +5V load increased to 2 ohms and -12V load removed.
Load Reg. $= \Delta V_0/V_0 = 0.11/5.1 = 2.2\%$
Line Reg. $\Delta V_0/V_0 = 0.005/5.1 = 1\%$

Summary

This design shows it is practical to work up to 100kHz without exotic transformers and output caps. It also shows that the continuous mode flyback circuit is the most practical high frequency circuit for a low power (50 to 100W) multiple output switcher. It requires the fewest number of output filter elements and usually does not require post regulators on the auxillary windings. Motorola has just introduced a single channel version of the 494 control IC. This part, the MC34060, will undoubtedly replace the 494 in most single-ended switcher applications becuase it offers the same performance features, but is more economical.

The FET switch was used experimentally here to show that speed and power handling are excellent and that drive circuits are relatively simple. In this 100kHz design, a good (fast) bipolar like Motorola's MJ16010

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Figure 12. Motorola FET Regulator, Top Side

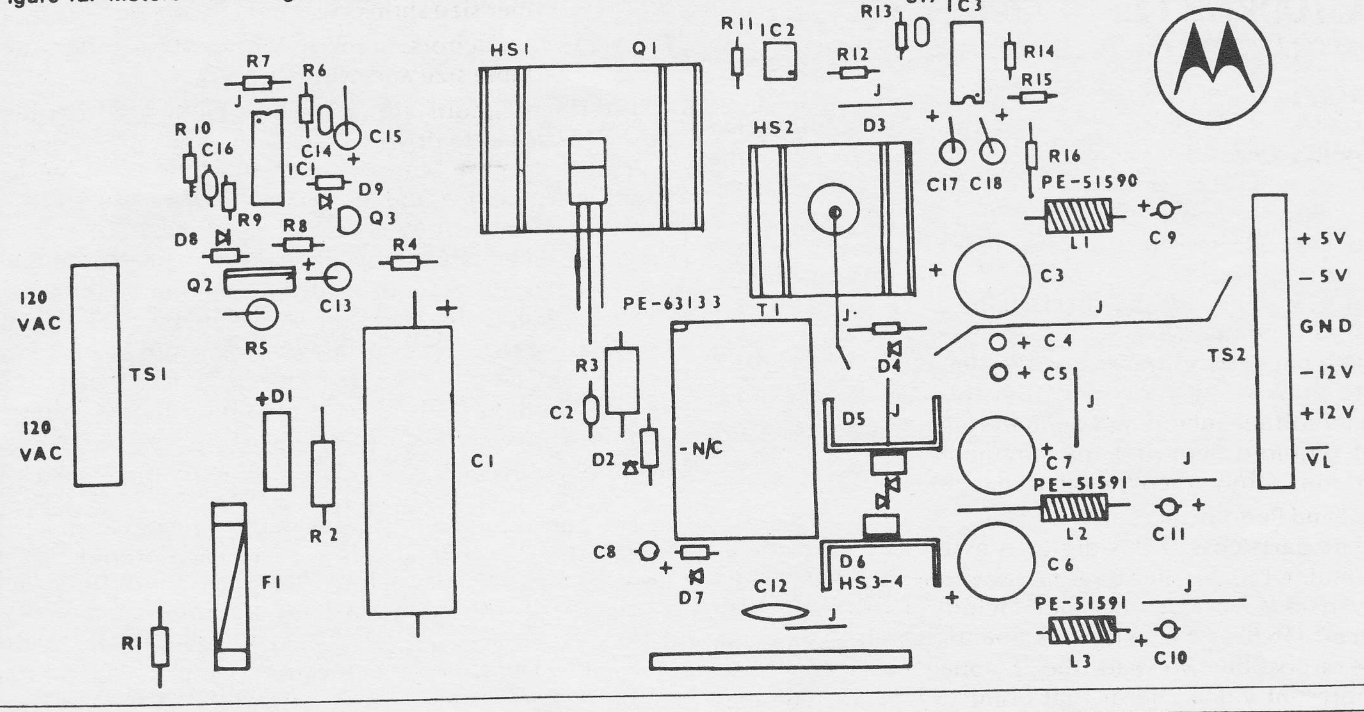
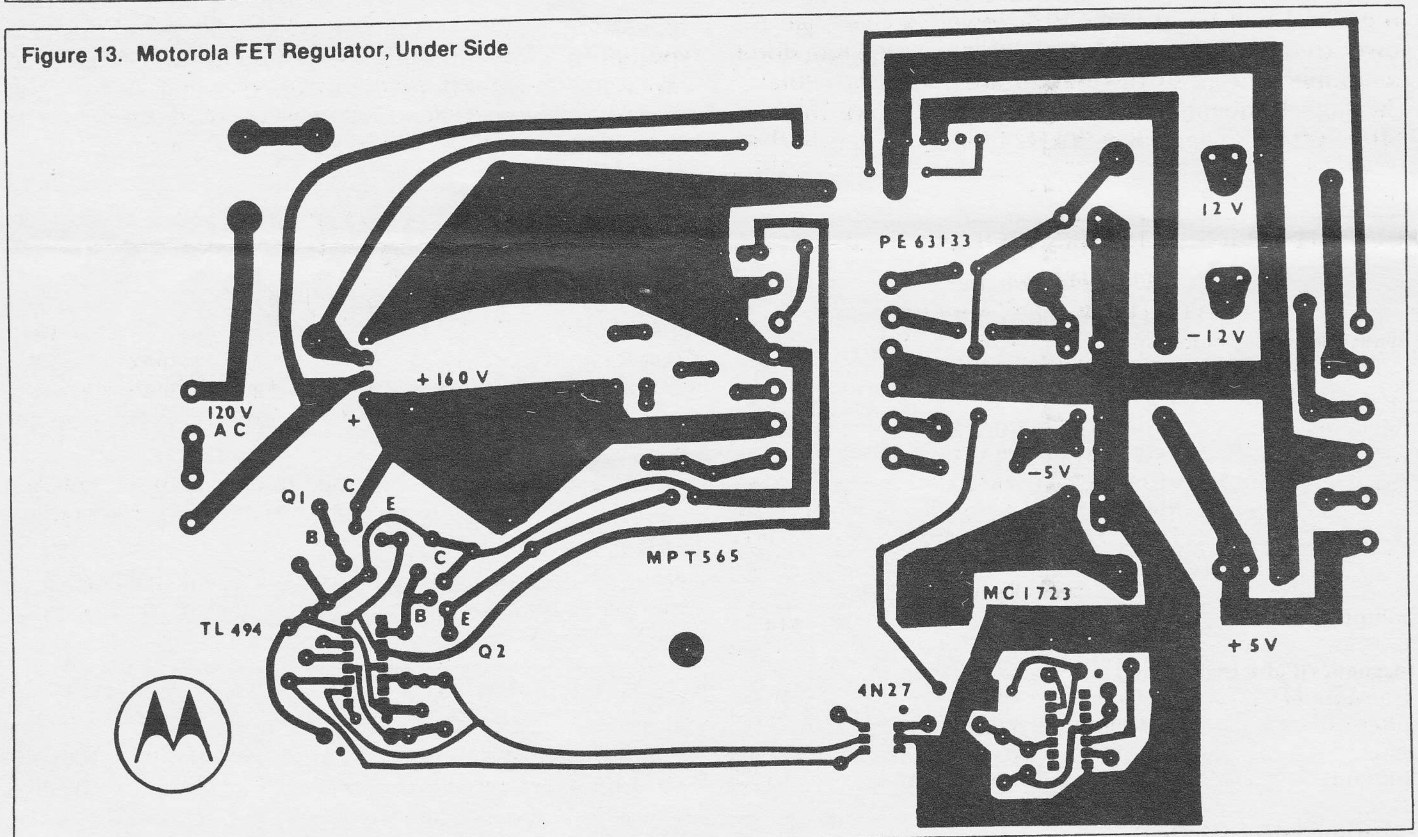


Figure 13. Motorola FET Regulator, Under Side



Switchmode III series could have also been used. However, in higher frequency designs the FET will be the designers choice simply to maintain good switching efficiency. And it's obvious that designers will want to push operating frequencies even higher (200 to 500k) to produce further gains in size and cost. The FET has already proven it can handle this. The challenge now is for the transformer and capacitor designer to become adept at handling these frequencies.

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EXTRA

Geroge McCrea EVAC Vancouver B.C. is arranging for hospitality bed and breakfast for EAA members. He requests you phone now (604) 663-3347.

The Canadains have offered to help cover the cost of a transporter for the EV's. Transport to start from central location(s). Arrangements must be made NOW! It is to late for letters! Phone Clarence Ellers (408) 248-2588 anytime up to 11:00p.m. PT.

To co-ordinate I need to know who is going, who is taking a car, and your length of stay. Again please phone me.

WHATS HAP'N

EAST BAY & CONTRA COSTA CHAPTERS

PG&E Service Center Mar. 8Th

Dave Burke will speak on the latest D.O.E. programs and costs. Also, two maintenance people from Concord Navel Weapons Station will speak on their Electric vehicle maintenance program.

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International Seminer on Rechargeable Batteries Mar. 3-4&5Th. (305)303-3099

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March 1986

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