SWITCHED MODE POWER SUPPLIES

Switched mode power supplies are now increasingly being used in broadcast equipment because of the advantages they offer over conventional power supplies. This information sheet outlines these advantages and introduces the most common techniques used in practical supplies.

SWITCHED MODE POWER SUPPLIES

1. CONVENTIONAL POWER SUPPLIES

1.1 The ac→dc converter

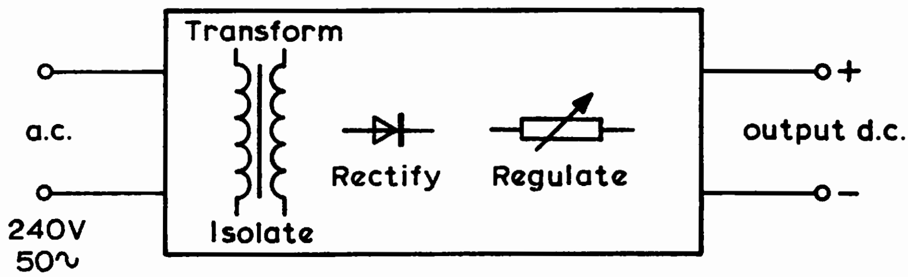


Figure 1

The transformer has two functions;

1. to transform the input voltage to near the required output voltage,
2. to isolate the supply output from the mains input.

The secondary voltage of the transformer is rectified and smoothed then regulated to produce the output d.c. This type of supply is essentially simple in operation. However it is usually size limited to the transformer and heatsink for the regulators - both of which are functions of worst case load and worst case mains voltage.

1.2 The dc→dc converter

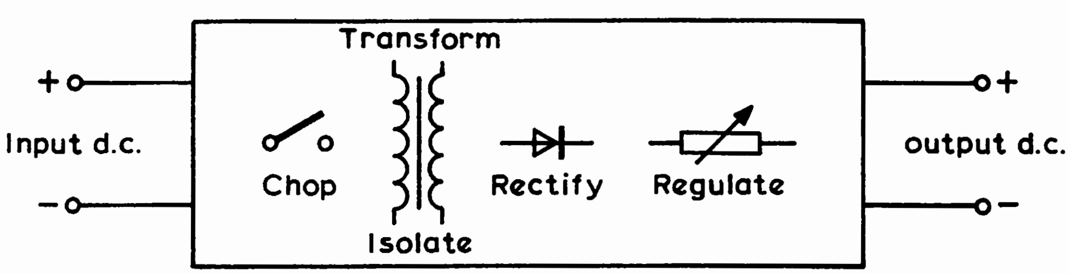


Figure 2

The input voltage is chopped to produce a fixed mark-space ratio extering the transformer. The supply is then as the ac→dc converter.

The chopping is usually carried out around 15 kHz. At this frequency the transformer core area reduces (*) however the regulators must still cope with worst case load and supply input.

* Emf of a transformer winding

$E = 4.44\ F\ B\ a\ N$

f = freq

B = max usable flux

a = cross sectional area of core

N = number of turns

$\therefore\ a \propto \frac{1}{f}$ for a constant number of turns

2. SWITCHED MODE PSU

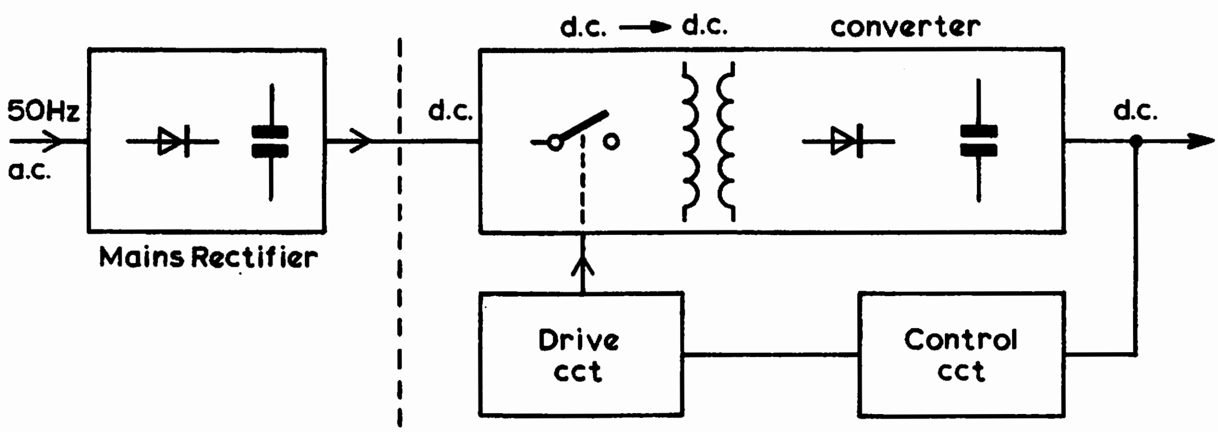


Figure 3

The basic arrangement of a switched mode power supply (SMP) is shown in figure 3. The mains input is first rectified and smoothed and the resulting dc voltage is chopped at high frequency (>20 kHz). The chopped waveform is applied to the primary of a transformer and the signal at the secondary is rectified and filtered to give the required dc output. The output voltage is sensed by the control circuit and a correction signal is produced which is used to vary the mark/space ratio of the chopped waveform and thus to compensate for any change at the output.

3. ADVANTAGES AND DISADVANTAGES OF SMPS

ADVANTAGES	DISADVANTAGES
Operation at high frequency (>20 kHz) reduces size of transformer with no audible noise.	Radio frequency interference generated.
Smaller capacitor required as the 100 Hz smoothing is at 300V (energy stored $\propto CV^2$, can volume $\propto CV$)	Special spike filter may be required to eliminate all traces of switching edges.
Large variations of input supply voltage and frequency possible.	
Regulator is more efficient. Conventional regulator $\eta \simeq 50\%$ SMPS $\eta \simeq 80+\%$	Regulation by feedback from dc output includes the output filter components and their associated phase shifts. This limits the bandwidth of the feedback amplifier so that transient response may not be as good as conventional PSU.

4. DC TO DC CONVERTERS FOR SMP's

4.1 Flyback (Ringing-Choke) converter (Figure 4)

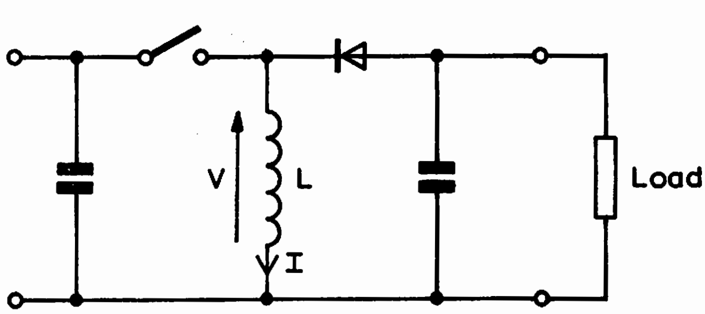


Figure 4

In the circuit of figure 4, when the switch is closed, the supply voltage is connected across the inductor and the output diode is non-conducting. Current rises linearly in the inductor until the switch is opened; at this point, the voltage across the inductor reverses and the energy stored is transferred into the output reservoir capacitor and the load.

The voltage and current waveforms will be as shown in figure 5 when on-off times of the switch are equal, giving an output voltage equal and opposite to the input voltage, (ignoring the voltage drop across the diode).

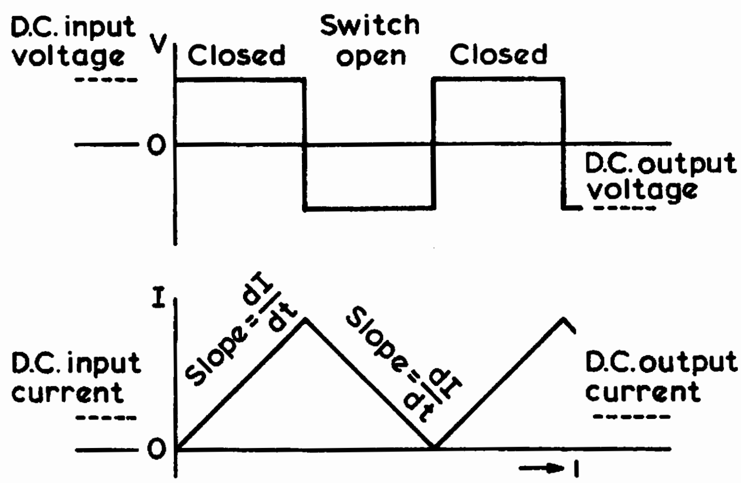


Figure 5

If the on time of the switch is halved, keeping the operating frequency and load resistance constant, the waveforms will be as in figure 6 below.

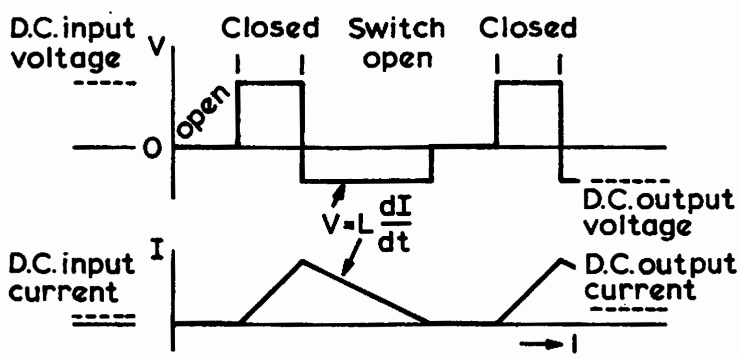


Figure 6

Note that the output voltage is halved demonstrating one method of controlling the output of a switched mode PSU.

4.1.1.Practical Realisation

Consider again the basic flyback converter circuit: (figure 7)

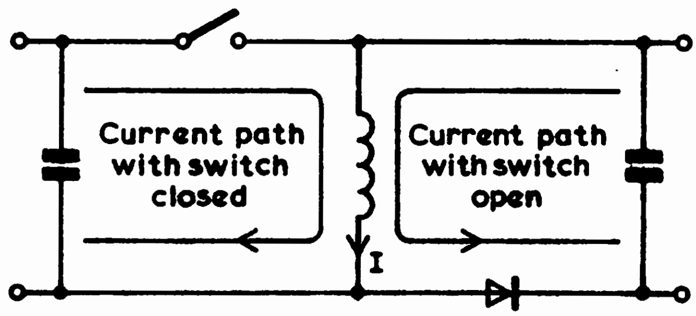


Figure 7

The inductor can be changed for a transformer to provide input/output isolation and voltage transformation, (figure 8) and the mechanical switch' for a transistor, (figure 9).

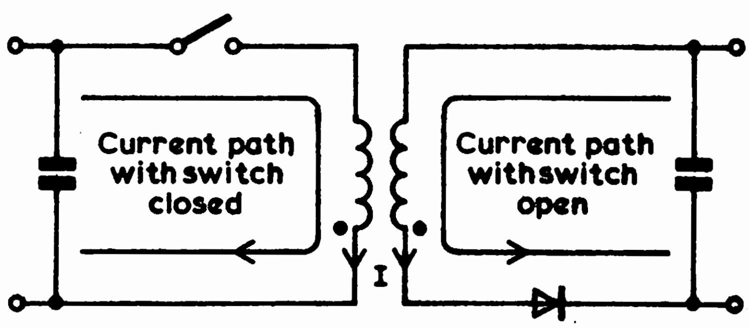


Figure 8

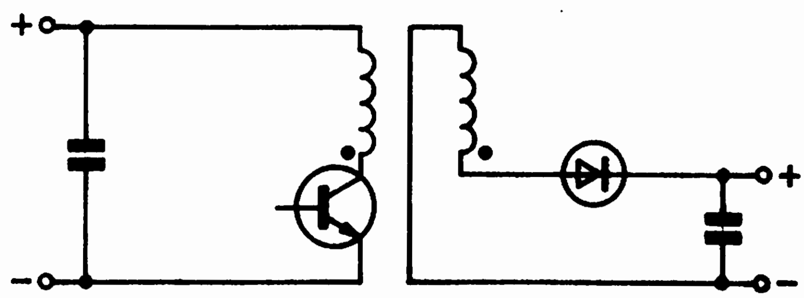


Figure 9

In a practical circuit, some leakage inductance will exist between the primary and secondary of the transformer. This leakage inductance has a detrimental effect on the operation of the circuit. When the current in the primary winding is stopped by turning off the power switching transistor, the rate of fall of the primary current will cause a voltage across the leakage inductance which can be considered as being in series with the primary. The size of the voltage spike will be determined by the switching speed of the power switching transistor and the size of leakage inductance. The equivalent secondary voltage together with the leakage inductance voltage may cause a primary voltage large enough for the collector-emitter voltage of a power switching transistor to exceed its rating, causing damage to the transistor.

The primary voltage may be limited to a safe value by winding a third winding with very low leakage inductance to the primary winding, so that the leakage inductance voltage between the primary and the third winding is very small. (Figure 10).

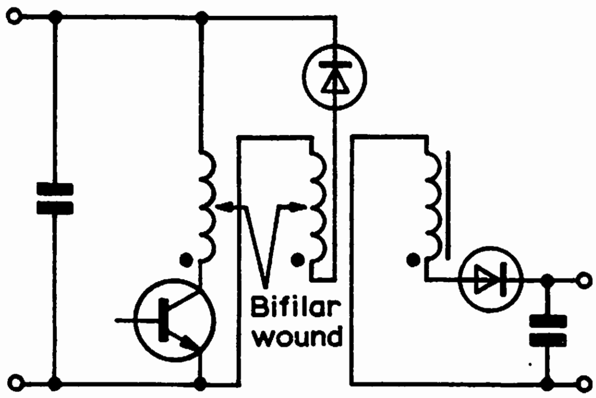


Figure 10

During the on time, no current flows through the third winding as polarity of the voltage across it is such as to reverse bias the diode. As the primary current falls at the end of the on time, the voltages on the transformer windings reverse. If the voltages on the third winding exceed the input voltage, the Diode D1 becomes forward biased allowing conduction in the winding and preventing any further increase in voltage, thus limiting the primary voltage. If the turns ratio is unity, the transistor collector voltage will be limited to twice the input voltage - for example if maximum input voltage is 375V then maximum collector voltage will be 750V. This voltage is normally higher than VCEO rating of the power switching transistor. To protect the transistor a slow rise circuit is necessary to ensure that the collector current has fallen to zero before the collector voltage exceeds VCEO rating (figure 11).

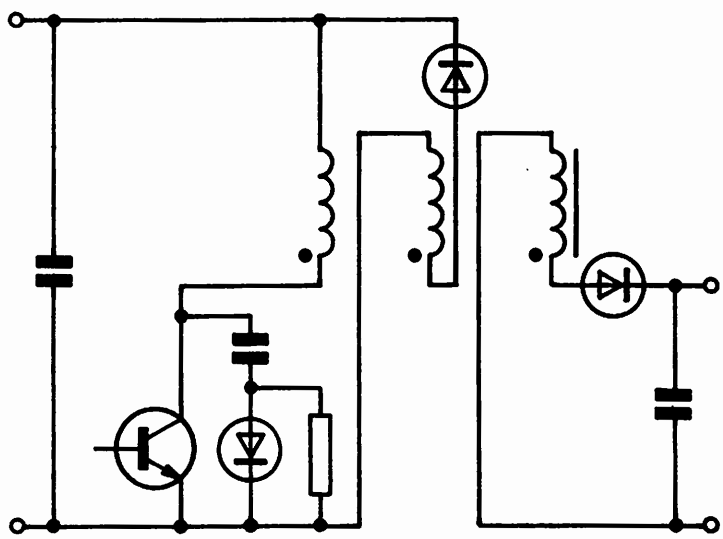


Figure 11

4.2 Forward (Feedthrough) Converter

In the flyback converter, energy is supplied to the load when the transistor is non-conducting. In the forward converter, the current in the secondary load is supplied by normal transformer action while the transistor is conducting.

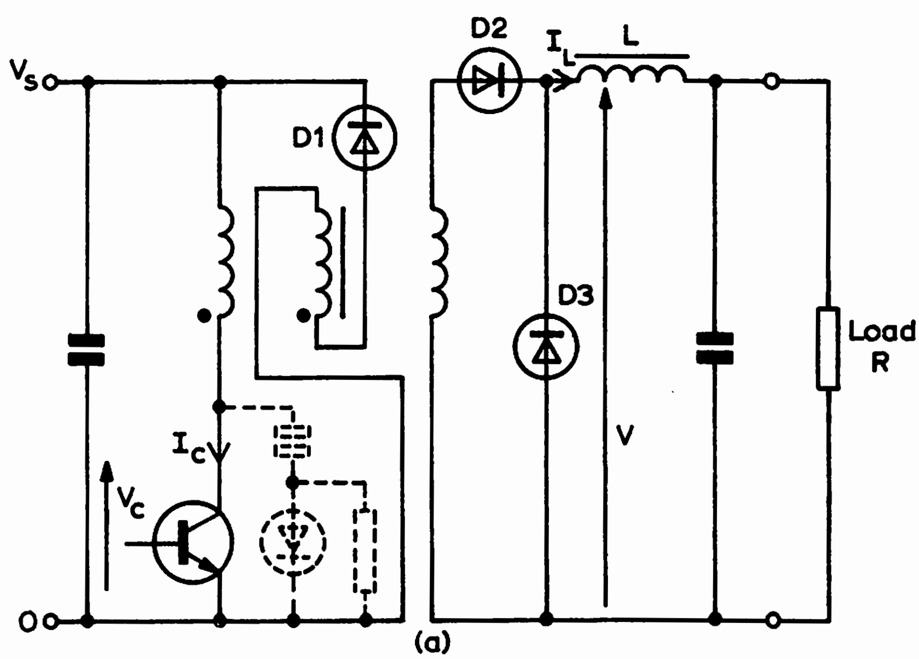
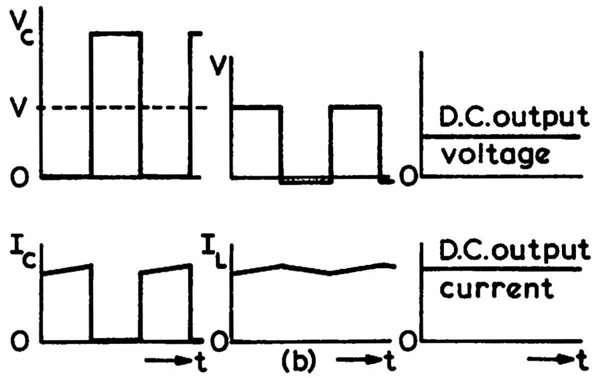


Figure 12

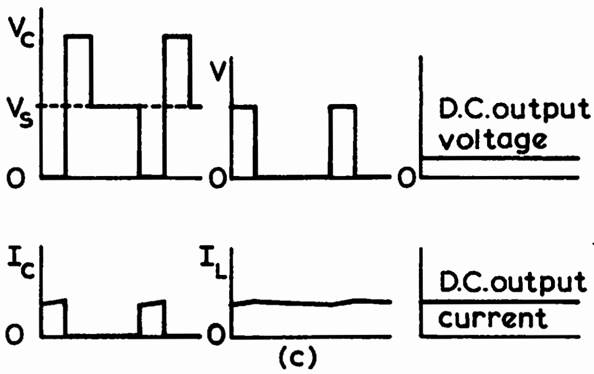
In the circuit of figure 12, an inductor L is included in series with the rectifier diode D_2 and the output terminal to make the output

voltage vary in accordance with the transistor on time. The second diode D_3 provides a path for the output current, which continues to be supplied by L when the transistor is not conducting. When the transistor is off, the transformer magnetising current is returned to the supply via the additional winding, bifilar wound with the primary, and the diode D_1.
Examples of the voltage and current waveforms for a forward converter are shown in figures 13 and 14.



Transistor with equal on off time.

Figure 13



Transistor with on time halved.

Figure 14

4.3 Push Pull and Bridge Converters

These circuits can be considered as extensions of the forward converter. The resultant output current has twice the ripple frequency thus reducing the size of output filter components. Also the excursion of the transformer core is through both halves of the BH curve during each cycle of operation, giving twice the rate of change of flux compared with a single ended converter. The size of the transformer may therefore also be reduced in push pull and bridge circuits. The penalty for this size saving advantage is in the increased complexity of drive circuit and the need to match transistor devices. An example of a push pull circuit is shown in figure 18.

5. APPLICATIONS

Three current (1979) applications of SMPs in use in the BBC are:-

1. Designs Department PSU for SONY KV 1340
2. Melford Monitor DU2 - 22C
3. Link 110 camera.

5.1 KV 1340 PSU

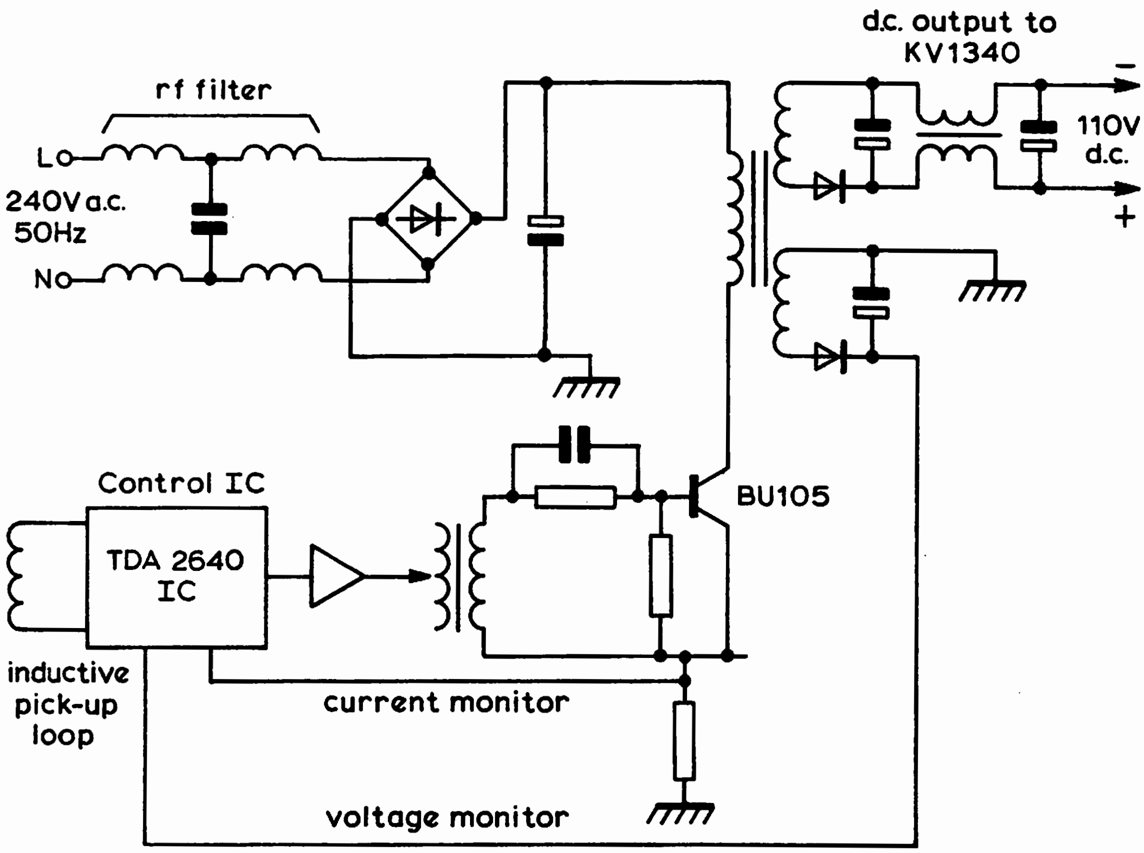


Figure 15

The above circuit produces an isolated 110V DC to power the modified KV 1340 colour monitor. The circuit makes use of the reduction in size and stray magnetic fields which SMP's offer. The heart of the unit is a commercial integrated circuit TDA 2640 which controls the flyback converter. The switching frequency is locked to television line frequency to reduce effects of SMP radiation on picture. The linelock signal is derived from an inductive pick up of line scan radiation.

5.2 Melford DU2 - 22C

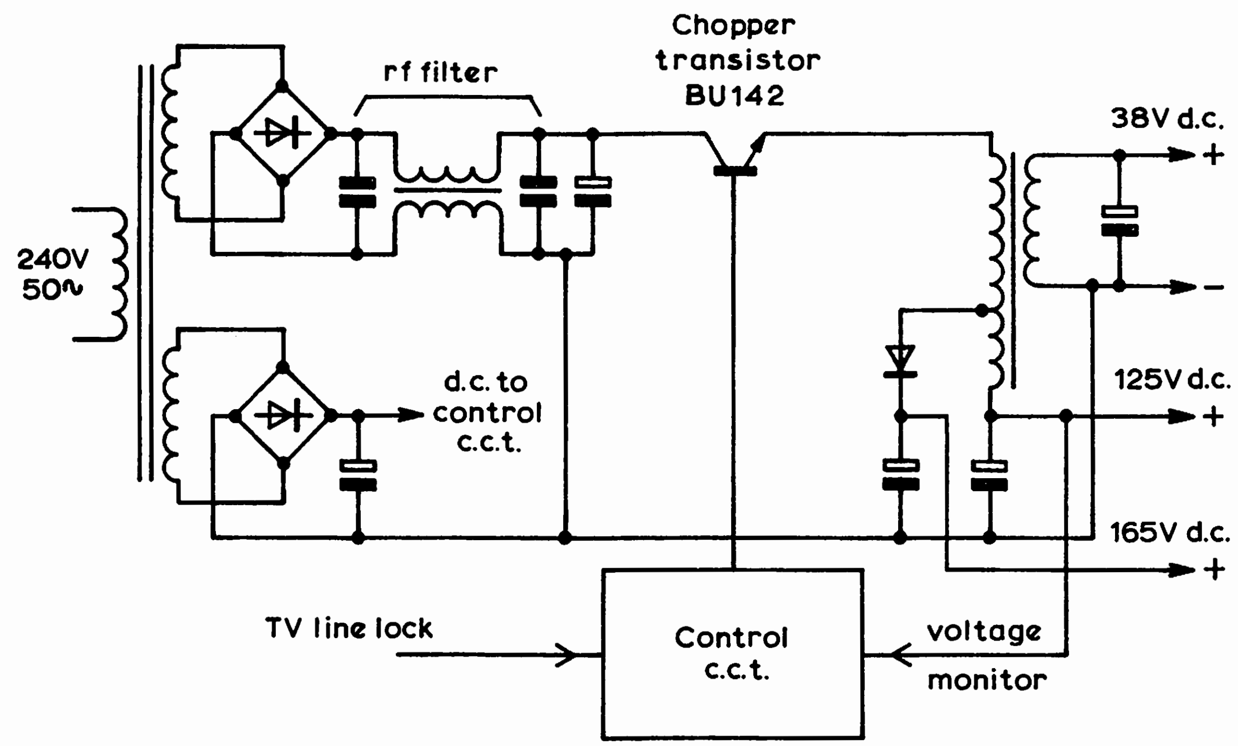


Figure 16

The Melford DU2 - 22C monitor uses an SMP to derive 125V dc stabilised, and 38V and 165V dc semistablised. The latter two require conventional regulators following the SMP. The circuit utilises the improvement in efficiency provided by SMP's, although it uses a conventional 50Hz mains input transformer. The 125V dc supply is fed from the chopper transistor via a series inductor, the 165V supply being tapped from this same inductor. A secondary winding on the inductor is used to give the 38V supply. As in the SONY PSU the chopper switching frequency is locked to television line frequency.

5.3 Link 110 Camera

The camera uses two conventional supplies for the low power applications but for the major power requirements of the camera head a switch mode p.s.u. is used.

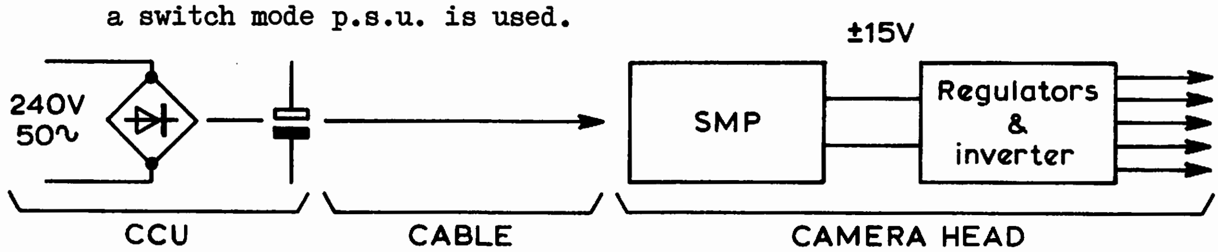


Figure 17.

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This approach reduces power disipation at the camera head to a minimum, without using a large number of camera cable cores.

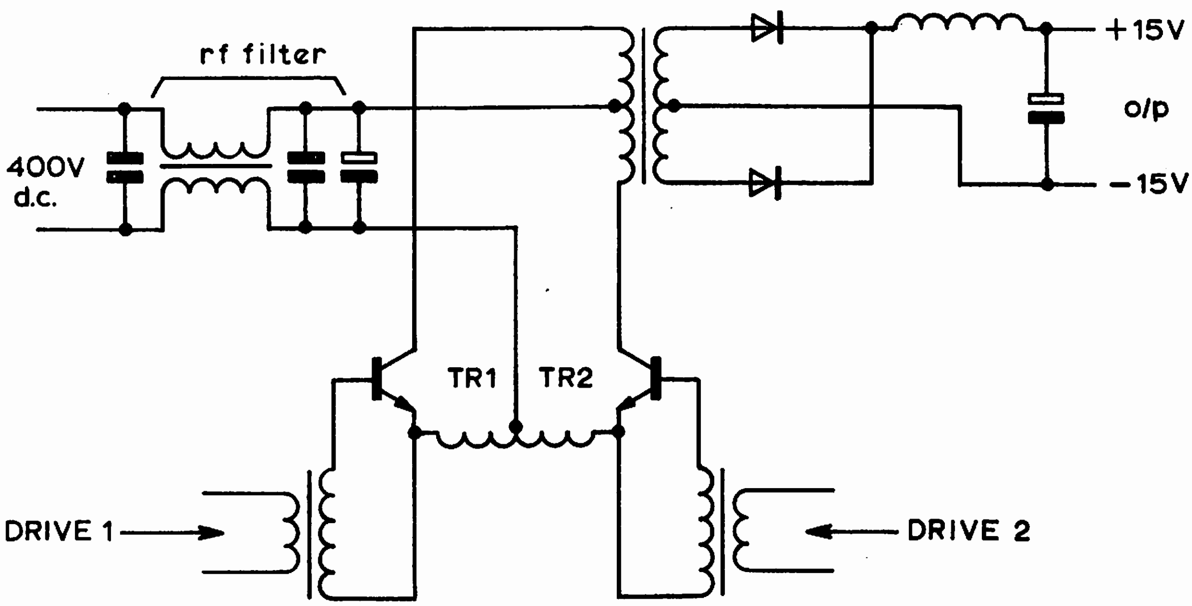

Figure 18

S.P. Westlake/VC
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