Switch Mode PS Principles

By G8MNY (Updated Dec 06)
(8 Bit ASCII Graphics use code page 437 or 850)
There are 2 types, they work slightly differently (when the secondary diode conducts), but both use high frequency LF into a ferrite cored transformer.

FERRITE TRANSFORMERS

With ferrite the eddy current losses are very small, & the BH curve magnetic cycle area which determine the power loss per cycle is also much smaller than for iron. (difficult to draw here).

```
                      ___
   IRON      │   _.-~~/              A MODERN  │     ..-'~
   LAMINATE  │./'  ./'               FERRITE   │   //
          ./ │   ./'                           │ //
      ────/──┼──/─── +H                ──────/┼/───── +H
       ./'   │/'                           // │
     ./' _./'│                           //   │
 __.:..-"    │-B                   _.-''      │-B
```

The high frequency means much smaller lighter transformers. For most ferrite cores the power handling is proportional to frequency. So a core running at 250kHz can handle say 250W, but at 50kHz only 50W.

```
Transformer 8 ┤                    _ . - ' ~ ` -._ eddy current &
   Power    4 ┤          _ . - ' ~                `-. BH losses
            2 ┤  . - ' ~                            \ win out
            1 └─┬────┬────┬────┬────┬────┬────┬────┬───
               5   10   20   40   80   160  320  640 kHz
```

The problems at these higher frequencies are the other circuit losses, not just the increased eddy current & BH losses in the ferrite, but inter winding capacitance, winding skin effect copper losses etc. External losses also increase, such as transistor on & off times (FET's can be fast if driven well), & diode rectifier on & off times & of course not to forget the increased radiation losses from all the wiring as the frequency goes up.

MAINS CIRCUIT

Both types of SMPSU start with a MAINS FILTER (not always fitted despite QRM laws!) the capacitors must be the "X" rated type for mains work, if earthed there will also be 4n7 caps to earth. Sometimes a Voltage Dependent Resistor is placed across the mains circuit in an attempt to protect the components from line voltage surges.

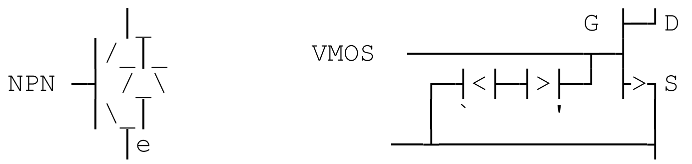
The turn on current surge is limited by a resistor (say 5R 10W or a thermistor & sometimes better put in the live feed) that feeds the bridge rectifier into either 2x 200V electrolytic or 1x 400V one.

```
                                   BRIDGE
                          SURGE ┌─┤>├───┬───────┬───┬─ +HT         ─┬─ +HT
  FUSE    MAINS FILTER    LIMIT │       │       │   │200V           │
L──o-o─┬──┬───┐   ┌───┬───┬──R──┴─┤<├─┐ │     100k ===     OR WITH  │
       │  │   (((()   │   │           │ │ Link  │   │      NO 110V  │ 300-380V
  Anti │ ===  =====  === VDR  ┌───────)─)─o o───┼───┤      OPTION  === MAINS
 shock R  │   (((()   │   │   │       │ │ 110V  │   │200V  WITH A   │ LIVE HT
N──────┴──┴───┘   └───┴───┴───┴─┬─┤>├─)─┘     100k ===     400V CAP │
            BALANCED            │     │         │   │               │
             CHOKE              └─┤<├─┴─────────┴───┴─ -HT         ─┴─ -HT
```

With the 2 caps a 110V mains option can be provided with just a wire link, that uses only half the bridge as a voltage doubler. (OK if mains 60Hz & the 2 caps are large value). These high voltage Caps no only have to store the charge between mains peaks but also handle the HF ripple load currents from the following class C switching stage. So the smoothing caps must be low Z at the pulse frequencies, so low equivalent series resistance ESR caps must be used, if the mains QRM is to be kept low.

SWITCHING TRANSISTOR
These are normally high voltage NPN or high voltage VMOS FET's nowadays. In theory if there are only ever off or on, there is almost no power to be dissipated. But the faster you operate them, to reduce the transformer losses the slower the edges are, when current at a voltage appears across them generating heat.

With NPNs a swinging low choke load that presents -ve voltage can turn the NPN on more than desired (slow to turn off then) so an internal diode is included in some NPN transistors & can confuse DC testing.

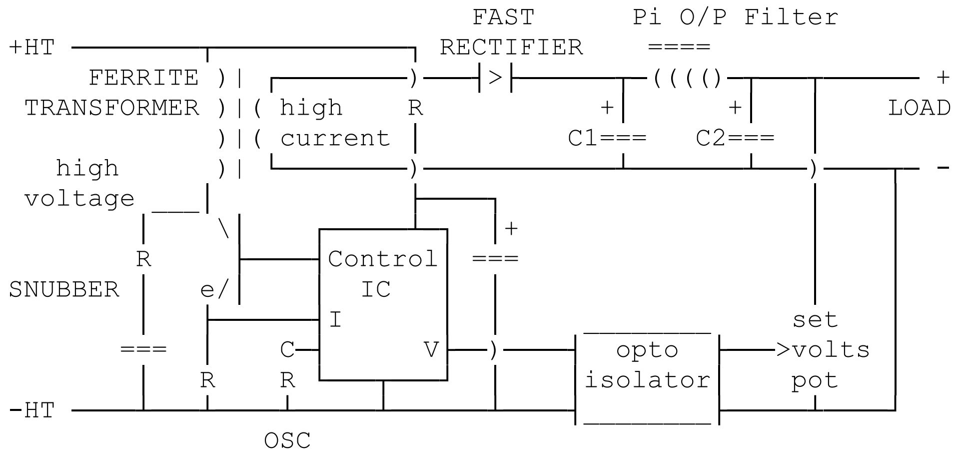


With VMOS over voltage on the gate drive will destroy the device, external zeners (15V) are often used back to back to clamp the drive, but some devices may have them internally.

These devices can be damaged by..
1/ too much current, e.g. overloads, sometimes damage is additive over time!
2/ too much voltage, e.g. 500V mains spike, burnt out snubber.
3/ too hot (too high dissipation/lack of cooling)
4/ under drive causing 3/
5/ overdrive damaging base/gate.
6/ repetitive heating (lifetime to 80°C may be 10,000x less than to 50°C)

EMP damage to other components is normal in SMPSU's when they fail & blow fuses!

SINGLE ENDED
These use the back emf or "ringing up" of the half cycle stored energy in the ferrite cored transformer. The transformer then does 3 jobs, provides isolation, provides step down ratio, & provide choke input filter. As only DC pulses are fed into the transformer only half the core BH curve energy can be utilised.



The phase of the transformer is arranged so that when the transistor is turned off the rectifier on the secondary conducts. The pulse width control IC can be powered from a HT dropper R, or added to by a secondary PS that takes over from the start up resistor to give enough drive current, or even a separate mains transformer.

The OSC CR sets the switching frequency, the IC also monitors the transistor current with a small value emitter R. Voltage feedback from the output drives an opto isolator to control the pulse width of the IC to alter the energy stored in the transformer for the next pulse. Sometimes other windings can be used but the regulation may be less accurate.

To stop the ringing up back EMF from damaging the transistor a snubber CR is used to terminate the +ve going HF high voltage pulse. Often a minimum load is needed to keep the size of back emf within safe limits.

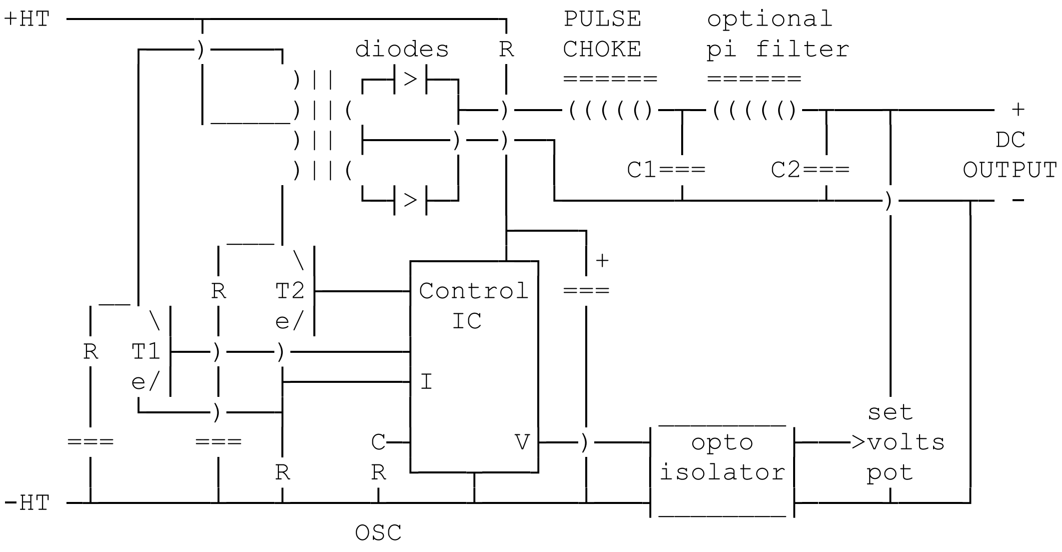
Due to the pulse current in the output is it usual to have a pi filter for the DC output, as a capacitor alone is not too effective.

```
                    Rectifier
Secondary│  ringing│__ on          │
voltage  │       up│  │  load off  │
         │         │  ║ ringing    │
      0v ┼──┐ pulse│  │└───┐       │       ┬ Height due
         │  │ width│ ║|    │       │       │ to mains V &
         │  │______│       │______│      _│_turns ratio
         │TRANSISTOR
         │   ON      OFF      ON
```

In the single ended SMPSU the diode rectifier only conducts when the transistor is turned off.

Output filter Caps C1 & C2 must have low ESR (Equivalent Series Resistance) otherwise they will not only do little filtering but heat up & dry out reducing their capacitance. This is a common fault with SMPSU's, & on complex equipment high levels of HF AC ripple on the output DC can cause all sorts of problems. (Scope the ripple on C1, if higher than 5% of the DC change C1).

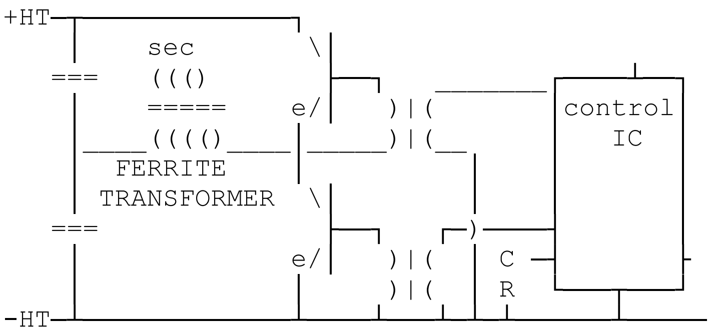
PUSH PULL 1
These are more complex & more powerful. The double action utilises the full power handling of the transformer core, but that means the secondary must be full wave rectified & an additional HF pulse choke (about the same size of the transformer) is now needed to convert the fixed height variable width HF voltage pulse to the mean output load voltage.



The control IC now has 2 drive outputs with not more than 45% on time, as each power switching transistor has to have some time to turn off before the other antiphase one is turned on.

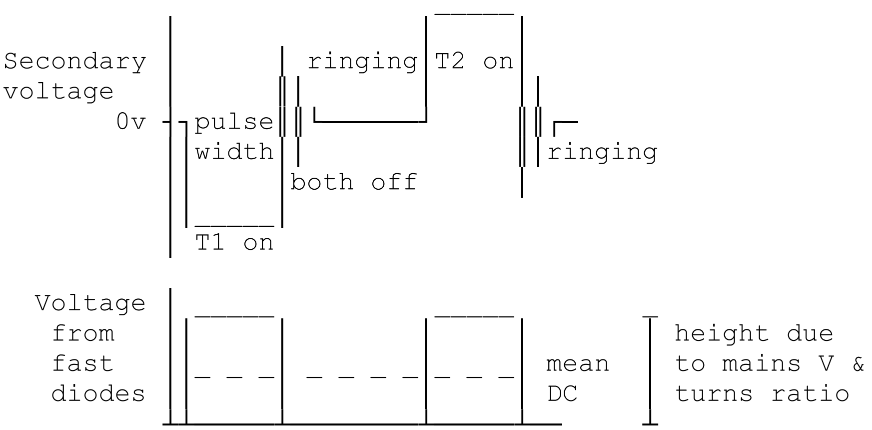
PUSH PULL 2

There is also a lower voltage design where the half rail voltage (2 Cs) is used to connect to the output transformer. This means the +ve rail transistor drive is hot so isolated driver pulse transformers are needed, normally used on both drives for symmetry.



In this case current monitoring may be done of the secondary circuit. Also the need for snubbers is less important as the output IN THEORY will not exceed the power rails.

PUSH PULL WAVE FORMS 1/2



on to off ratio depends on load current & supply voltage

The output diodes conduct when the transistors are on, pumping energy into the pulse choke. As the pulse choke can be made big enough to still give current between primary pulses (when there is no incoming source voltage so both diodes may conduct) sometimes a pi DC output filter is not used.

SAFETY

1/ Working on them it is recommended you use a mains isolation transformer.
2/ Use a high voltage 1/10 or 1/100 scope probe, rated at 600V @ 100kHz not one rated at 400V @ 100Hz!
3/ If in doubt if the HT is discharged when off, use a discharge R e.g. 10k 5W.
4/ Use the "one hand behind the back" safety precautions on HT circuits!

FURTHER READING

See my buls on "Stopping HF Tx/Rx SMPS QRM", "Reducing Electronic RF QRM" & the crowbar part of "High AMP crowbar protected PSU".

Why don't U send an interesting bul?

73 de John G8MNY @ GB7CIP