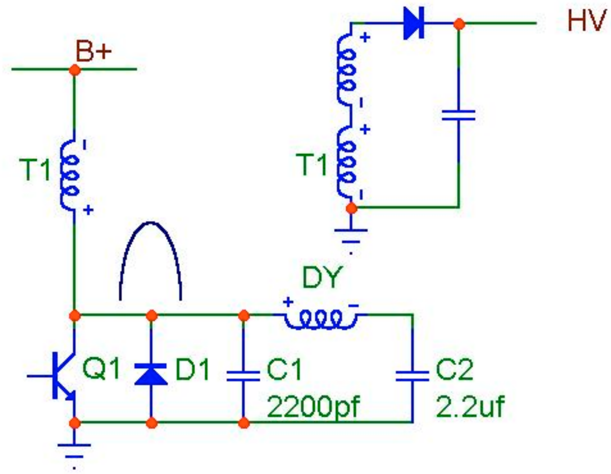
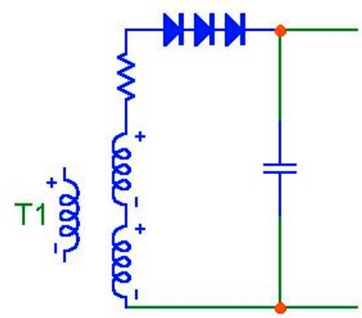
Basic High Voltage / Horizontal Deflection

In a monochrome monitor it is common to get the high voltage from the horizontal deflection circuit. The retrace pulse is multiplied by the turn ration of the transformer T1 to get high voltage.

The supply voltage B+ controls both the horizontal size and the high voltage. In the design process B+ is chosen to get the proper size and C1 (the fly back capacitor) is chosen for the proper width and height of the flyback pulse. Many flyback transformers have taps on the primary used to set the proper turn ratio.



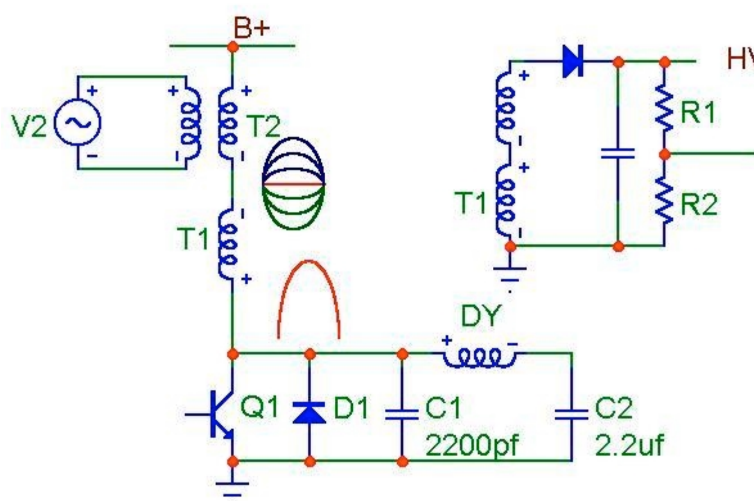
High voltage transformers do not have good regulation. Generally high voltage transformers have bad primary to secondary coupling. The insulation and separation needed to handle the high voltage reduces coupling. Large turn ratios also cause poor coupling. The large number of turns require a long length of small wire. Wire resistance causes poor regulation. The high voltage diode is not simple. It may have 20 to 30 volts of drop.



How to control the HV with out effecting the horizontal Size?

Transformer T2 is added in series with the flyback transformer T1. Sense the average voltage across T2 must be zero the addition of T2 will not effect the size of the picture. A signal V2 is placed across T2 in synchronous with the horizontal scan. The size and phase of the signal V2 will add or subtract from the flyback pulse as seen by T1 but will not effect the flyback pulse as seen by the deflection yoke. In this way the high voltage can be regulated with out effecting the deflection.

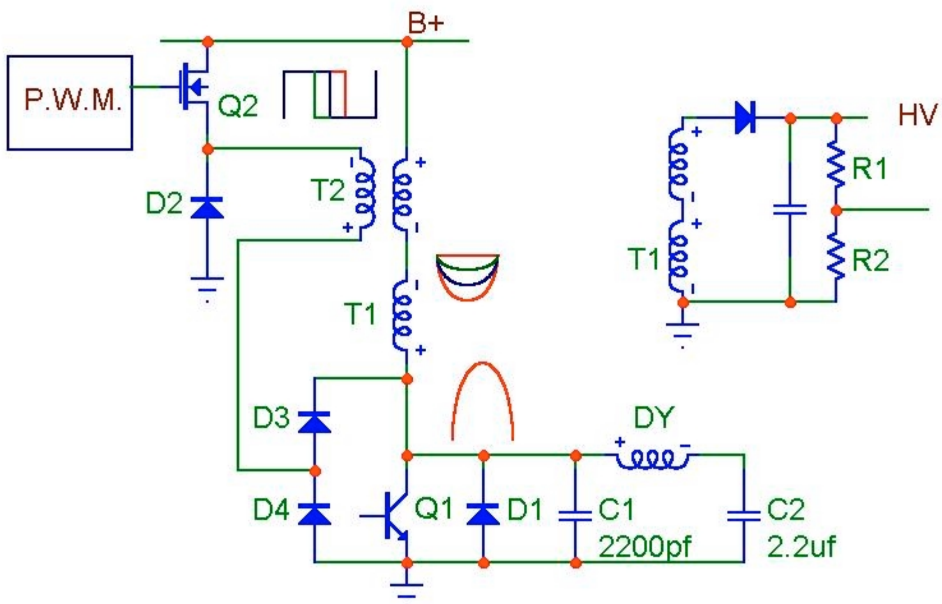
see US paten #4,614,899



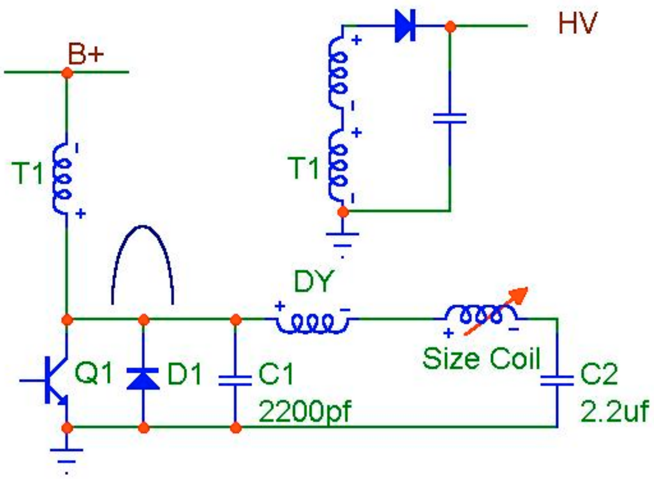
A practical application of a switched mode high voltage regulator.

Resistors R1 & R2 form a voltage divider that feeds into the error amplifier of the Pulse Width Modulator. Any variation in the high voltage will be seen by the PWM causing a change in duty cycle on the gate of Q2. During Trace Q1/D1 are closed. Through D3 the voltage on the bottom end of the primary of T2 will be near ground. The voltage across T2 primary will be zero volts when Q2 is open and B+ volts when Q2 is closed. While Q2 is closed energy is stored on T2. During retrace the collector voltage of Q1 will swing upward in a half sign wave. The bottom end of the primary of T2 will kick upwards by some amount that is equal to or less than the flyback pulse.

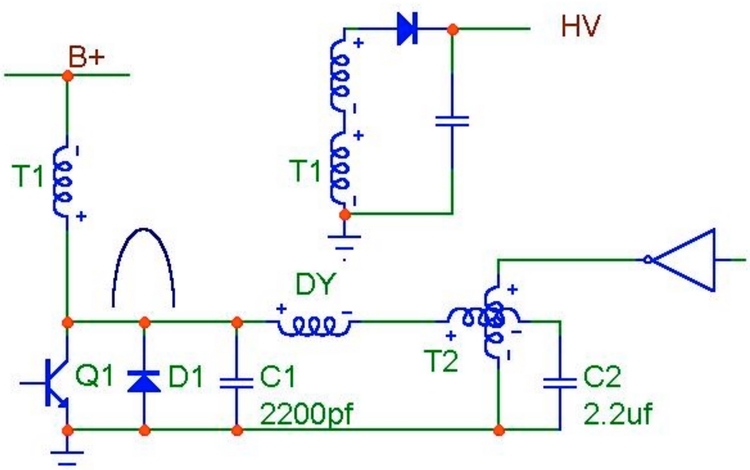
During flyback we need a 20,000 volt pulse on the + end of the secondary of T1 under no load conditions. If the flyback transformer has 5% load regulation then under load it's voltage will drop about 1000 volts. To get regulation the pulse will have to be busted up to 21,000 volts under load. Through the 20:1 turn ration the primary will need a 1000 volt pulse on the + lead (1050 volts under load). The variables in the horizontal section (B+, C1 & DY) should be chosen to create a flyback pulse slightly smaller than the 1000 volts needed for high voltage. If the flyback pulse is 950 volts then the secondary of T2 will need to push downward 50 volts to get 1000 volts across T1. Under load conditions T2 will need to develop 100 volts to hold the high voltage constant. Typically T2 has a 10:1 turn ration that allows for 10% changes in high voltage.



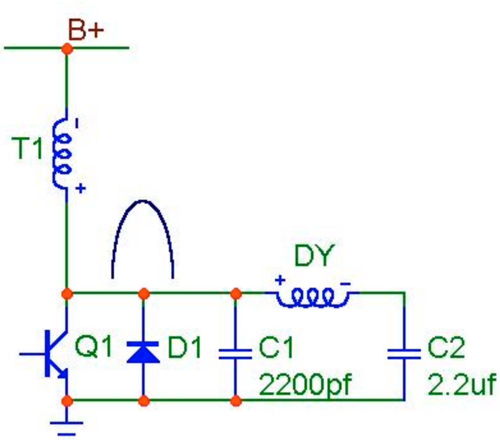
In monochrome monitors typically the ratio of horizontal size to high voltage is adjusted by the addition of a size coil. The coil will change the effective inductance of the DY. If the size coil changes the total inductance by 10% the deflection current will have the same 10% change while the high voltage will change by the square root of 10%.



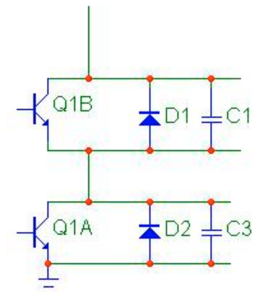
The pin cushion transformer is a size coil that is electrically controlled by passing a D.C. current through the control winding.



Before talking about the split diode modulator we need to review the operation of a horizontal section. The supply has a supply voltage of B+. The voltage at the collector of Q1 is zero volts during trace and is a high voltage half sign wave during retrace. The average voltage is the same as B+. The voltage across C2 is the same as B+. Current in C2, DY, Q1 and D1 is typically ten times that flowing through T1. It is important to remember that the "power supply" that delivers power to the DY is C2 not B+.



The split diode modulator has two horizontal sections, one above the other. To make things simplifier to understand you could think of the two horizontal sections as completely separate. Transistors Q1A and Q1B can be combined into one transistor. I know it is hard to understand how one transistor Q1 can do the work of two transistors. Trust me it works!

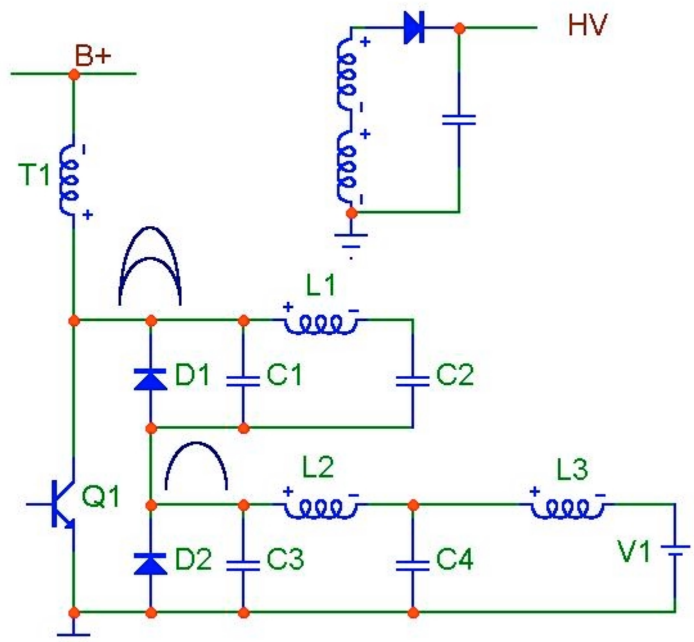


Again to make things easier to understand lets declare the two horizontal sections to be of equal value. (L1=L2, C1=C3, C2=C4) These values are not typical. In our example (for now) lets remove L3 and V1. The flyback pulse is equal to the voltage across C1+C3. The voltage across C2+C4=B+. The current through L1 comes from voltage stored on C2, and likewise the current through L2 comes from voltage stored on C4. So fare in our example current in the two inductors are equal. Now add back in L3 and V1 with it's voltage set to ½ B+. Nothing changes!

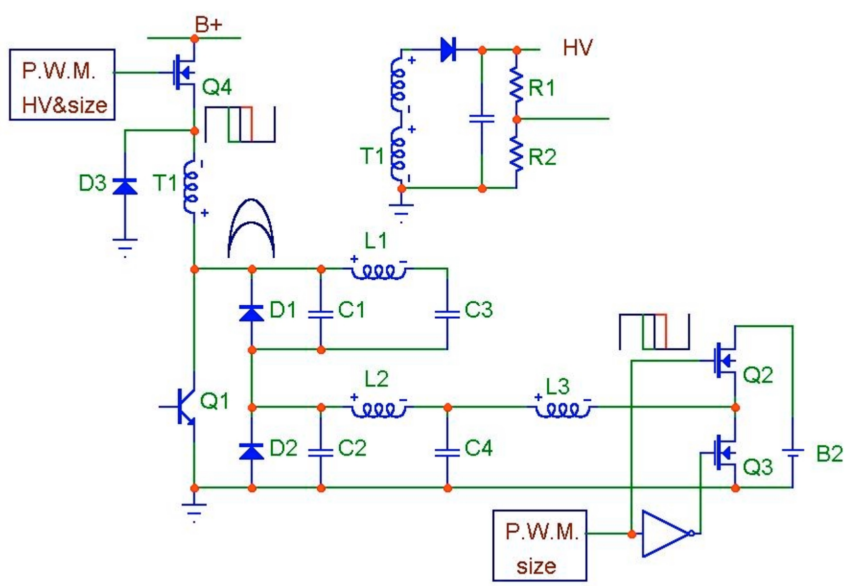
The voltage source V1 can set the voltage across C4 from near zero volts to near B+. The current through L2 is directly related to the voltage across C4. Because the voltage across C4+C2=B+, the current through L1 is related to the supply voltage B+ minus V1.

If the current in L2 is dropped by 10% then the current in L1 must increase by 10%. The sum of the two currents will remain constant. To say that another way; the two flyback pulses will change by +10% & -10% with the addition of the two remaining constant.

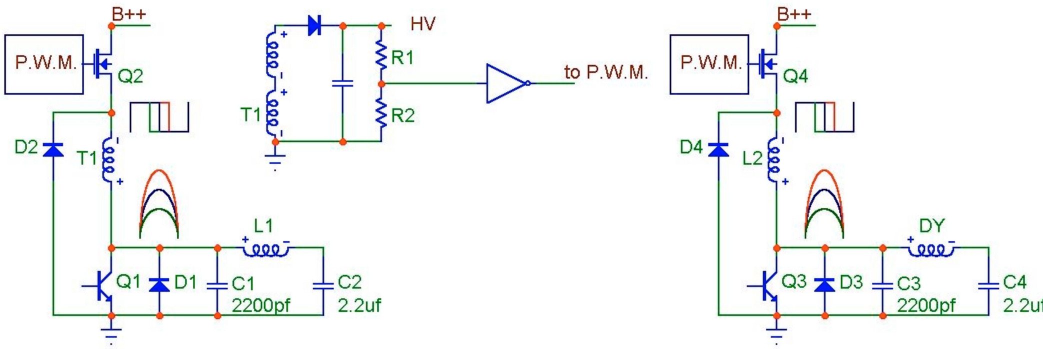
One of the two coils is the deflection yoke and the other is a "dummy coil" or "modulation coil". V1 sets the size of the picture. B+ controls the high voltage and possible the picture size.



V1 can be a supply or an active load that pulls down. The most efficient method is to make a switcher that pushes or pulls. In this example the size PWM watches horizontal size while the HV PWM watches the high voltage.

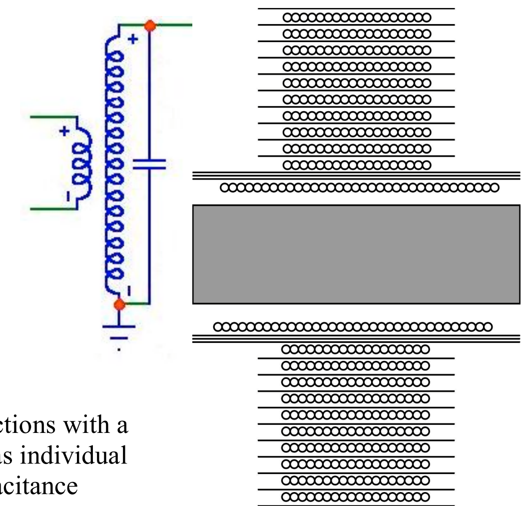


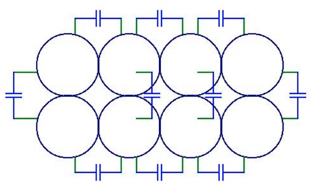
The high voltage and horizontal can be made in separate circuits. This eliminates the interactions of high voltage load on horizontal size and size on high voltage. The high voltage is monitored by a tap on the bleeder resistor inside the flyback transformer. The horizontal size can be monitored by numerous methods.



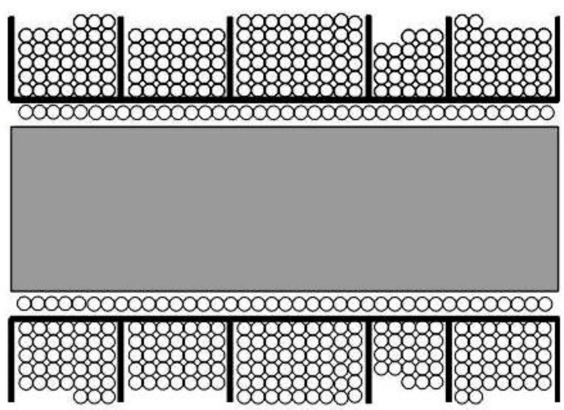
High voltage transformers have a large numbers of turns. Capacitors form between each wire in side the transformer. Inter winding capacitance causes the transformer to resonate. Some transformers are tuned to resonate at 3, 5 or 7 times the frequency of the flyback pulse. The gap in the core is set to get the proper frequency. This type of transformer excludes multi sync use.

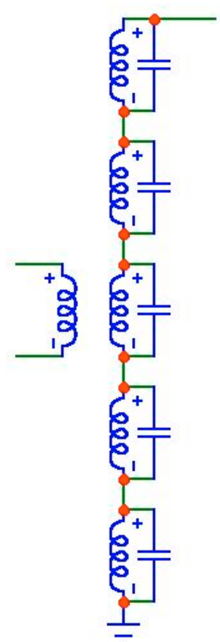
The primary and secondary windings are separated by layers of tape. Each layer of the secondary is built on a layer of tape. The windings are kept back from the edge of the tape. The entire winding area is covered with insulating material.



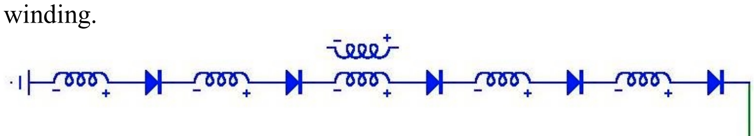


The next trick is to break up the winding into smaller sections with a high resonant frequency. The slot wound transformer has individual “small” slots divide up the secondary. There is still capacitance between wires but the walls of the slots break up the capacitance. Windings usually have a different number of turns and thus a different resonant frequency. Stager tuned transformers allowed for multi-frequency monitors. Notice that each slot may be of different size and has a different number of turns.

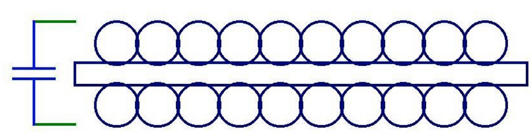




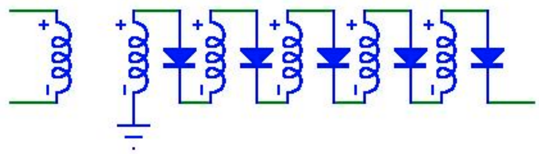
The windings can be broken-up by spreading out the diodes between each winding.



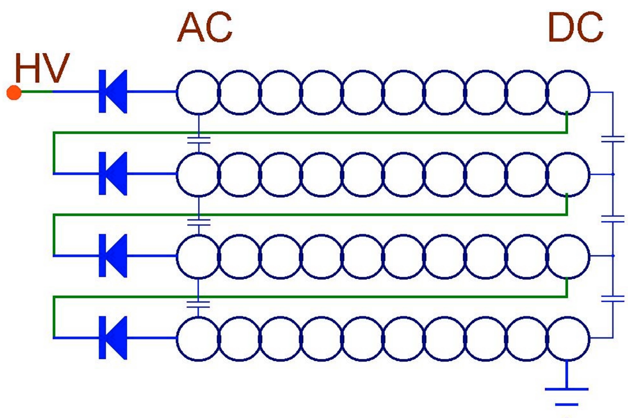
Each layer of wire forms a capacitor with the next layer of wire. Adding layers of tape reduces the capacitance but can not eliminate it.



While the capacitance can not be eliminated it's effect can be eliminated. If there is no A.C. voltages across a capacitance no current will flow. In this example the secondary has been divided up into four (or many) pieces each wound from right to left in one layer.



The bottom layer starts at ground and has a large A.C. signal at the left side. The signal is rectified by a diode to make D.C. that connects to the start of the next winding. In this way all layers of wire have D.C. on the left side and an identical A.C. signal at the right side. There is only D.C. between layers (no A.C. signal between layers). No A.C., no current flow hence, no capacitance effect.

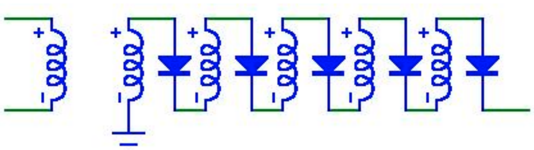


Wire to wire the capacitance (in a single layer) has relatively little effect. If there is one volt per turn then each cap will have 1 volt A.C. across it. From layer to layer there may be a hundreds of volts A.C. and each cap will have a large amount of current.

Multi layer transformers

Back when all CRT terminals operated at 15,750 Hz a flyback transformer secondary might have 20 to 30 layers of wire. As horizontal frequencies moved up to the 31,750Hz range A.C. losses and low resonant frequencies became a problem. The A.C. wire losses increases exponentially with the number of wire layers. At higher frequencies the winding needs to be wider with less layers. Dividing a ten layer winding into two five layer windings with a diode between then will cut the A.C. wire loss in half while dramatically reducing the resonant frequency. (17+17=34 which is about ½ of 67) A secondary broken into 10 one layer windings with diodes between each will have A.C. wire losses of 10/67 that of a 10 layer winding.

Layers	1	2	3	4	5	6	7	8	9	10
A.C. wire loss	1	3	6.3	11	17	24	33	43	54	67



The argument has been used that the horizontal frequency is only 80kHz, wire loss should not be a problem. Actually the flyback pulse is about 3 times the horizontal frequency.

The next argument is that because the flyback pulse is sign wave (half sign wave) there should not be any high frequency harmonics present. I disagree with this to. Most high frequency flyback transformers have an anti-ringing circuit hidden at the bottom of the high voltage winding. This masks part of the high frequency voltage and currents found in the HV winding. A current probe placed inside the transformer and a voltage probe placed around the anti-ringing circuit will reveal large amounts of energy well into the mega-hertz region.