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UNDERSTANDING HORIZONTAL OUTPUT STAGES OF COMPUTER MONITORS

Today's computer, medical, security, design and industrial video display monitors operate at a host of different horizontal resolutions or scanning frequencies. Many change modes to display video at several scan frequencies while others adapt to display a range of horizontal scan frequencies or resolutions.

All CRT based video displays have horizontal stages including a horizontal output stage. Some use two horizontal output stages, one to produce high voltage and another to produce horizontal yoke current. The frequency of the horizontal output stage(s) must match the video's horizontal sync or scan frequency. Despite the wide range of operating frequencies and uses, several basic horizontal output circuit configurations are common.

This Tech Tip examines the common horizontal output stage configurations found in multi-frequency CRT video displays. It provides details on how these stages operate and what to expect for normal voltages and waveforms to improve your troubleshooting.

The Basics Of A Horizontal Output Stage

All horizontal output stages have 4 key components and require two essential inputs. These are listed below.

All horizontal output stages operate in a similar manner. A power supply voltage (B+ voltage) is applied to the stage, typically to one side of the transformer or coil. (See Fig. 1.) The power supply provides the current to energize the transformer or coil. When energized, alternating sawtooth currents in the transformer primary or coil winding are produced. Induced voltages from the transformer or coil develop high voltage and/or yoke current.

An H.O.T. (horizontal output transistor) provides a path for current to energize the transformer primary or coil winding. The transistor's emitter-to-collector current path is switched fully on or off by an input drive signal. Horizontal output stage transistors can be a conventional bipolar type or newer N-channel enhancement MOSFET.

A retrace or timing capacitor (Ct) is used to tune or time the horizontal output stage. With the H.O.T. switched open, the timing capacitor forms an LC tuned circuit with the transformer or coil winding. The timing capacitor slows the rate of the transformer or coil's collapsing magnetic field controlling the level of induced voltage.

A damper diode parallels the horizontal output transistor. The diode is biased on with induced voltage from the flyback or coil during a critical time in the output stage cycle. The damper diode's conduction path prevents reverse breakdown current in the horizontal output transistor resulting in transistor heating and failure. The damper diode permits energy stored in the transformer or coil at the end of the output stage cycle to be returned to the B+ supply. The damper diode is a fast switching high voltage, high current diode.

Four Key Components:
1. Horizontal Output transistor
2. Transformer Primary or Coil
3. Retrace Timing Capacitor
4. Damper Diode

Two Essential Inputs:
1. B+ Power Supply Voltage
2. Input Signal Drive

High Voltage or Deflection Only Horizontal Output Stages

Multi-frequency video display monitors may have one or two horizontal output stages. A display with one horizontal output stage combines the yoke and flyback transformer into a circuit which produces both high voltage and horizontal yoke deflection current simultaneously. When a video display contains two horizontal output stages, one horizontal output stage is responsible for producing high voltage while a second output stage produces horizontal yoke current.

A multi-frequency video display is more likely to have two horizontal output stages if the CRT size is greater than 15 inches. Separate HV and deflection horizontal output stages are rarely found in monitors with CRT sizes less than 15 inches or in televisions because of the added cost. Larger CRT display monitors requiring higher yoke current and larger current changes to accommodate multi-frequency operation are more likely to have separate high voltage and deflection output stages. Design of a horizontal output stage to satisfy the yoke current requirements and maintain reliable operations is simplified when separated from the high voltage generating horizontal output stage. Separating the output stages allows each to operate with much less current (power)

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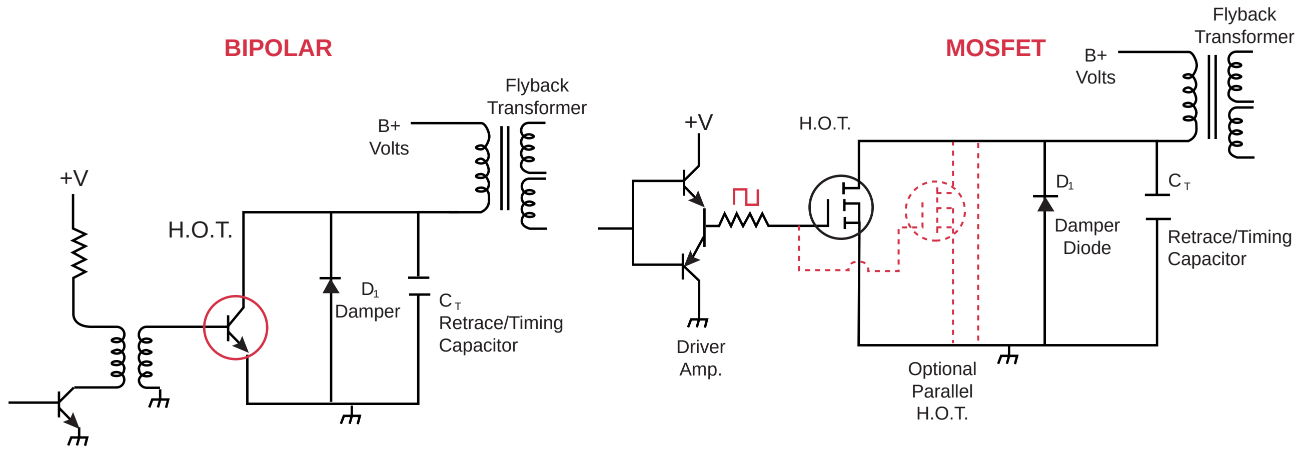

Fig: 1: Typical bipolar and MOSFET high voltage only horizontal output stages and their driver stage.

requirements than if combined.

A typical high voltage only horizontal output stage consist of a flyback transformer, timing or retrace capacitor, damper diode and horizontal output transistor(s) as shown in Fig. 1. Either a bipolar transistor, MOSFET transistor or paralleled MOSFET transistors may be used.

Because of the reduced current in a high voltage only horizontal output stage compared to a combination stage, a MOSFET horizontal output transistor can be used reliably. In cases where the current is still substantial, matched paralleled MOSFET transistors may be used to divide the H.O.T. conduction current for increased reliability. Considering the reduced costs of MOSFETs and drive components, the cost of a mosfet compared to a bipolar horizontal output transistor is slightly better.

Two important differences exist when using a MOSFET horizontal output transistor compared to a bipolar type. First, the flyback voltage pulses induced into the output stage must be reduced because MOSFETs have a lower breakdown voltage rating than bipolar transistors. Secondly, the input drive signal and driver circuits must be different to match the differences in the MOSFET's transistor's operating characteristics. For these reasons bipolar and MOSFET output transistors cannot be interchanged.

Today's MOSFET horizontal output transistors typically have a maximum voltage rating from drain to source of either 800 volts or 1000 volts. In comparison, bipolar transistors have a maximum voltage rating collector-to-emitter of 1500 volts. Typically, flyback pulses in MOSFET output stages are at least 100 volts under their maximum rated voltage or less than 900 volts peak-to-peak. In comparison, flyback pulses in a bipolar transistor output commonly exceed 1000 VPP. Lesser induced voltages are compensated for with a different flyback transformer turns ratio to produce the needed high voltage.

A MOSFET transistor is a voltage operated device while a bipolar transistor is a current operated transistor. Switching a bipolar transistor on requires that the drive produce base current of several hundred milliamps. The base drive current switches the transistor fully on enabling it to conduct collector currents of several amps. A MOSFET output transistor turns fully on when positive voltages greater than 4 volts are applied to the gate. The input signal typically ranges from near 0 volts (H.O.T. off) to between 5 and 15 volts (H.O.T. on). When switched on the MOSFET transistor reduces its drain-to-source resistance path to less than 2 ohms permitting peak currents to build in the flyback primary winding.

Because MOSFET and bipolar output transistors have different input drive requirements, the horizontal driver stages for each are considerably different. Driver stages for bipolar output transistors use an amplifier and current stepup transformer to produce the needed drive current to the bipolar transistor's low impedance base. Driver stages for MOSFET output transistors use an amplifier to provide a changing voltage to the MOSFET'S high impedance gate.

High Voltage Only Horizontal Output Stage Operation

Operation of the high voltage only horizontal output stage is fundamental to all horizontal output stages. When the H.O.T. is driven on by the drive signal, B+ current increases through the H.O.T. collector energizing the transformer or coil winding. The current is opposed by the inductance increasing at a near constant rate reaching a peak of several amps. The magnetic field builds in the transformer or coil's core during this time inputting the power required to produce high voltage. The B+ supply voltage, coil inductance, H.O.T. conduction time, beta and base current drive all effect the level of energizing current buildup.

When the H.O.T. is switched open, the timing capacitor (Ct) is effectively placed into the circuit forming an LC resonant circuit. Immediately after the H.O.T. is switched off, the magnetic field of the transformer or coil begins to collapse. The collapsing magnetic field causes current to flow through the low impedance of the B+ supply capacitor charging Ct. This is the beginning of the retrace time and corresponds with horizontal sync. As the timing capacitor charges, a rising voltage is produced at the collector or drain of the output transistor. The voltage reaches its peak as the magnetic field is fully collapsed.

The timing capacitor performs a critical function in slowing down the rate of the collapsing magnetic field. If the capacitor value decreases or is opened, the field collapses much more rapidly producing a much higher induced voltage, several thousand volts or more. The induced voltage would produce excessive high voltage and/or deflection and quickly damage the horizontal output transistor. Because of this key role in controlling the flyback or kickback voltage, the timing capacitor is often called a "safety capacitor".

After the magnetic field has completely collapsed, Ct begins to discharge, causing current flow back into the transformer or coil in the opposite direction. A magnetic field builds, but with the opposite magnetic polarity. This action completes the second part of retrace and corresponds to the falling portion of the voltage waveform or pulse at the collector or drain of the H.O.T.

When Ct has completely discharged the magnetic field of the transformer or coil begins to collapse. The collapsing field induces a voltage with a polarity that forward biases the damper diode. The damper diode conducts producing an inductive circuit similar to when the H.O.T. was conducting. The damper diode allows the magnetic energy of the transformer or coil winding to decay at a controlled inductive rate returning energy (current) back to the B+ supply capacitor. As the magnetic field is nearly fully collapsed the horizontal output transistor is turned on and the cycle repeats.

Deflection Only Horizontal Output Stage

A deflection only horizontal output stage is responsible for producing yoke deflection current. This horizontal output stage contains the basic components of a horizontal output stage plus components which

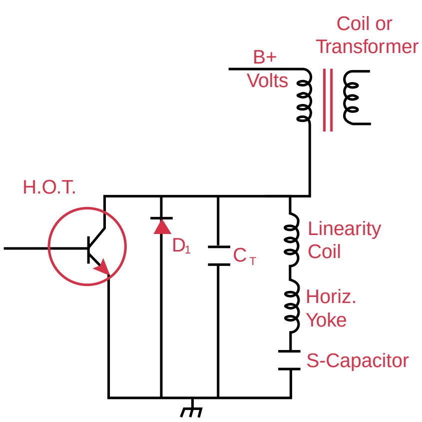

Fig. 2: Basic deflection only horizontal output stage.

comprise the yoke's current path. A typical deflection horizontal output stage is shown in Fig. 2. Because of the yoke's high current requirements, bipolar output transistors are used. A high frequency coil or transformer replaces the flyback transformer.

The horizontal yoke and its series components parallel the timing or retrace capacitor of the horizontal output stage. Included in the yoke's current path is always a linearity coil and an "S-shaping" capacitor. These components shape the rise and fall of the alternating current in the yoke to produce a linear and uniform deflection on the CRT. The series components can be arranged in any order. Other components that may be found in the horizontal yoke's current path are a pincushion transformer and efficiency or width control transformer or coil (not shown in Fig. 2).

Operation of a deflection only horizontal output stage is the same as described for the high voltage only horizontal output stage, but with the additional path for yoke current. To produce yoke current that is in sync with the video's horizontal retrace time, a common horizontal drive signal originating from the locked horizontal oscillator feeds the separate HV and deflection output stages. The common horizontal drive synchronizes the high voltage and deflection output stages to produce flyback pulses at nearly the same time.

Current for the horizontal yoke is derived from the output stage's retrace or timing capacitor. When the H.O.T. is turned on, the bottom side of the S-shaping capacitor connects to the top of the linearity coil. Because the S-shaping capacitor is fully charged from the previous cycle, it begins to discharge through the horizontal output transistor. The resulting current flow produces an expanding magnetic field in the linearity and yoke coils. The polarity of the increasing current deflects the CRT's electron beam from the center to the right. At the same time, B+ power supply current flows through the H.O.T. to energize the transformer or coil winding.

When the horizontal output transistor is switched open, the retrace timing capacitor effectively is placed in parallel with the yoke and its series components increasing the resonant frequency or rate of current change in the yoke. The yoke's magnetic field rapidly collapses producing current which charges the retrace timing capacitor and S-shaping capacitor. Because of the difference in capacitor values, most of the energy is returned to Ct. Corresponding with this time, is the collapsing magnetic field of the B+ transformer or coil which replenishes or fully charges the retrace capacitor. You may recall this is the rising edge of the inductive "kickback" voltage pulse at the collector of the output transistor. Now, fully charged, Ct becomes the current source for the yoke for the remainder of the cycle. This time corresponds to the 1st part of retrace when the CRT's electron beam is quickly returned to the center of the display.

During the 2nd part of retrace, Ct and the S-shaping capacitor produce discharging current through the yoke in the opposite direction. The current rises to a peak building the magnetic field in the yoke and quickly moving the electron beam from the center of the CRT to the left. Also, during this time, Ct is energizing the B+ supply transformer or coil.

When the retrace capacitor and the S-shaping capacitor are fully discharged, the yoke's magnetic field begins to collapse. This corresponds with the collapsing magnetic field of the transformer or coil energized by the B+ supply. The induced voltage forward biased the damper diode into conduction. The circuits timing now agrees with the timing during the right trace time when the H.O.T. was conducting. The yoke's collapsing magnetic field returns energy to the circuit charging the S-shaping capacitor. Yoke current moves the CRT's electron beam slowly from the right to the center of the CRT. When the yokes magnetic field is collapsed, the damper diode stops conducting. This corresponds with the beginning of the H.O.T.'s conduction and the cycle repeats.

Indirect Flyback Driven – HV Only Horizontal Output Stages

In most high voltage horizontal output stages the flyback primary winding is in the direct current path of the horizontal output transistor. However, there are several nonconventional horizontal output stage configurations in which the flyback primary is not in the H.O.T.'s conduction path.

For example, Fig. 3 shows a high voltage only horizontal output stage in which the flyback transformers primary current is provided by the retrace capacitor Ct. This configuration is nearly the same as the deflection only horizontal output stage of figure 2. The only difference is that the yoke is replaced by the flyback transformer primary winding. Recall that when the H.O.T. is switched on by gate drive, B+ supply current flows to energize the coil and produce an expanding magnetic field. When the H.O.T. is switched off, the coil's magnetic field induces voltage and charging current to Ct. Ct then becomes the supply or current source of flyback current. Current alternates in the tuned circuit including the flyback transformer primary in the same manner as described earlier for the deflection only horizontal output stage.

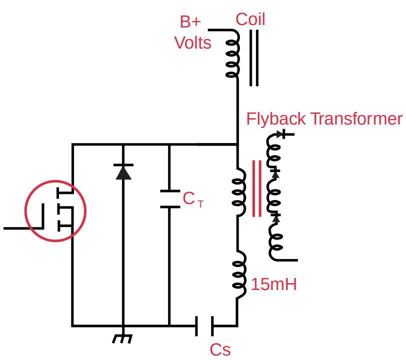

Fig. 3: Indirect current drive to the flyback transformer.

Combination High Voltage and Deflection Horizontal Output Stages

A combination high voltage and deflection horizontal output stage produces high voltage and yoke current simultaneously. There are 3 common combination horizontal output stage configurations found in multi-frequency display monitors. They include:

1. **Single Damper type**
2. **Split or Dual Damper type**
3. **Emitter Driven type**

Single Damper Combination Horizontal Output Stage

A common combination horizontal output stage is the single damper horizontal output stage. The single damper combination horizontal output stage is used in the majority of television receivers. The single damper output stage produces high voltage and deflection with the fewest parts and component costs. It offers good performance and reliability for single frequency operation. The single damper output stage is also popular in computer display monitors that operate over only a few frequency modes or a limited operating frequency range.

The single damper diode output stage can be recognized by the fact it has only one damper diode. (See Fig. 2). The diode is placed from the H.O.T. collector to emitter. The damper diode may be a discrete component or integrated into the bipolar horizontal output transistor.

In a single damper diode horizontal output stage, the flyback transformer primary winding connects from the collector of the output transistor to the B+ power supply. The yoke and series components connect between the H.O.T. collector and emitter or ground. The timing capacitor provides energy to produce yoke current much like the deflection only horizontal output stage.

Operation of the single damper horizontal output stage is identical to the deflection only horizontal output stage explained earlier. The only exception is that the coil between the collector and B+ supply is replaced with the primary winding of a flyback transformer. Conduction of the H.O.T. energizes the primary of the flyback transformer. When the H.O.T. is switched off the collapsing magnetic field of the flyback transformer charges Ct. The charge in Ct produces current in the yoke and flyback transformer primary. The damper diode shunts the H.O.T. and is biased into conduction by the induced voltage from the flyback and yoke to return magnetic energy to the power supply.

While the single damper diode combination output stage reliably produces high voltage and deflection current with the fewest components and costs, it is limited in multi-frequency applications. This is because any changes to the output stage to increase high voltage would also increase yoke current and vice versa. With extreme horizontal frequency changes it becomes difficult to change the operating parameters to both establish normal high voltage and proper yoke deflection current simultaneously.

For a complete explanation of a single damper diode combination horizontal output stage request Sencore Tech Tip #207.

Split Damper Combination Horizontal Output Stage

A popular combination horizontal output stage found in multi-frequency video displays uses two damper diodes. The damper diodes are placed in series from the collector to the emitter of the H.O.T. (See Figure 4) This horizontal output stage also uses two timing capacitors placed in series between the H.O.T.'s collector and emitter. A connection in the middle of the damper diodes and timing capacitors splits the output.

The split damper diode and timing capacitor configuration provides a means to control the level of yoke deflection current while not impacting the flyback current and resulting high voltage. It furthermore provides a method of achieving pincushion correction and other dynamic modifications of the horizontal yoke current.

An understanding of the operation of a split damper horizontal output stage can be gained by analyzing the currents and resulting voltages during 4 times during the horizontal cycle, starting with the conduction time of the H.O.T. (See Fig. 5). When the H.O.T. is switched on by base drive, current increases through the flyback primary

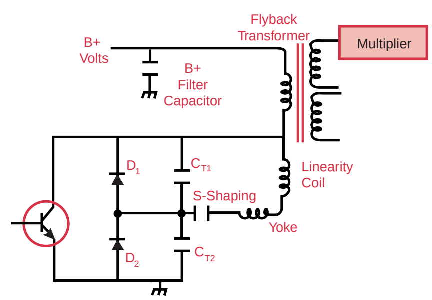

Fig. 4: A split damper combination horizontal output stage.

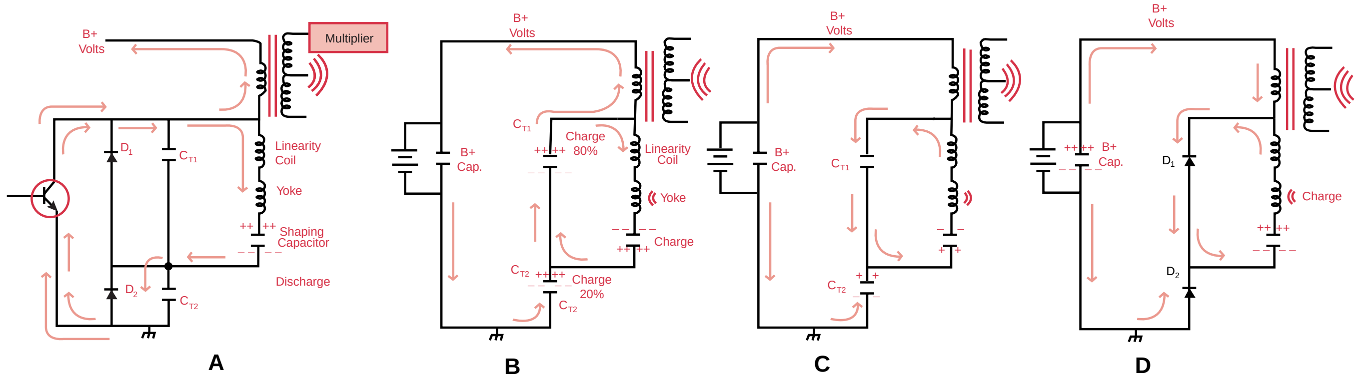

Fig. 5: Operation of a Split Damper Combination Horizontal output stage cycle.

creating an expanding flyback magnetic field. Current is also supplied from the S-shaping capacitor charged from the previous cycle. Current flows from the S-shaping capacitor through the bottom damper (D2), H.O.T. linearity coil and yoke. Yoke current deflects the CRT's electron beams from center to the right of the picture.

When the H.O.T. is switched off, the magnetic fields in the flyback and yoke collapse. The flyback's collapsing magnetic field produces induced voltage and charging current to timing capacitors CT1 and CT2. Values of Ct1 and Ct 2 are chosen so approximately 80-90% of the charge is delivered to CT1 and 10-20% to CT2. The yoke's induced voltage produces charging current to CT1 and the S-shaping capacitor. The difference in capacitor values returns the greatest charge to CT1. This portion of the cycle is the 1st part of retrace which quickly returns the CRT beam from the right to the center of the picture.

With the flyback and yoke magnetic fields fully collapsed, capacitors CT1 and CT2 begin to discharge. Capacitor CT1, now fully charged, supplies discharge current along with the lesser charged S-shaping capacitor to the horizontal yoke. The yoke current moves the CRT's electron beam from the center to the left completing retrace. Capacitors CT1 and CT2 produce current through the flyback primary, but in the opposite direction, producing an expanding magnetic field.

When the timing capacitors are discharged, the flyback's magnetic field collapses biasing on the damper diodes. Diodes D1 and D2 conduct providing a current path for the magnetic energy of the flyback to recharge the power supply filter capacitor. The collapsing magnetic field of the yoke charges the S-shaping capacitor with current flowing through D1. Yoke current moves the CRT electron beams from the left slowly to the center. When the yoke magnetic field is fully collapsed, the S-shaping capacitor nears full charge. The H.O.T. is then switched on to repeat the horizontal cycle.

Emitter Driven Combination Horizontal Output Stage

Most horizontal output stages in multi-frequency display monitors are single damper or split damper type, but occasionally a modification to these will be encountered. One such change is found in several computer display monitors from Gateway and several other manufacturers. The modification changes the manner in which the H.O.T. is switched on and off by the input drive signal. (See Fig. 6) All other operations of the output stage are the same as the single damper combination output stage.

The emitter driven horizontal output stage places a switching MOSFET at the emitter lead of the bipolar horizontal output transistor to ground. The horizontal drive signal is applied to the gate of the MOSFET turning its source-to-drain conduction path on or off. Effectively the emitter lead of the H.O.T. is connected to ground when the MOSFET is switched on. The supply

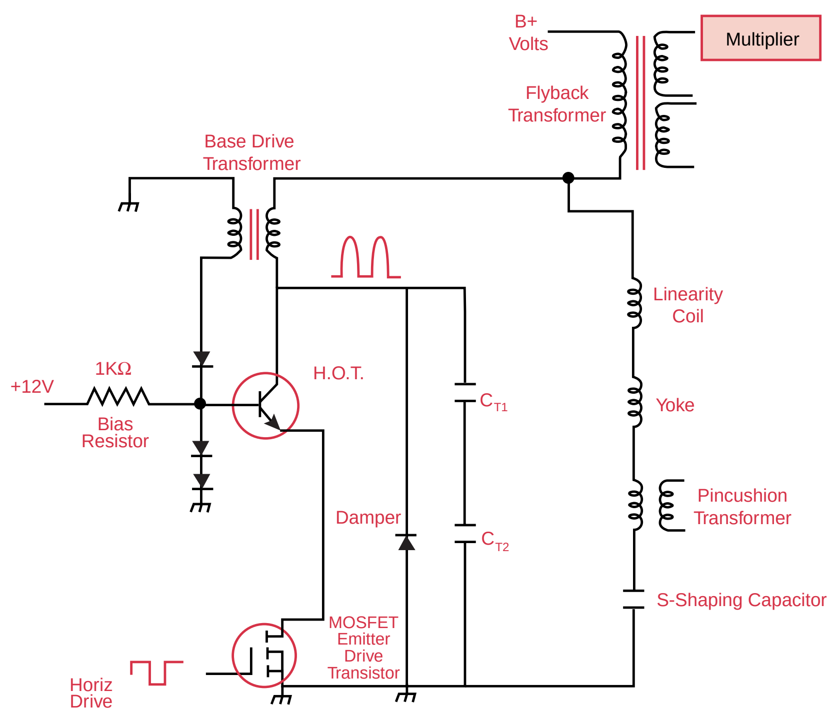

Fig. 6: Emitter driven combination horizontal output stage.

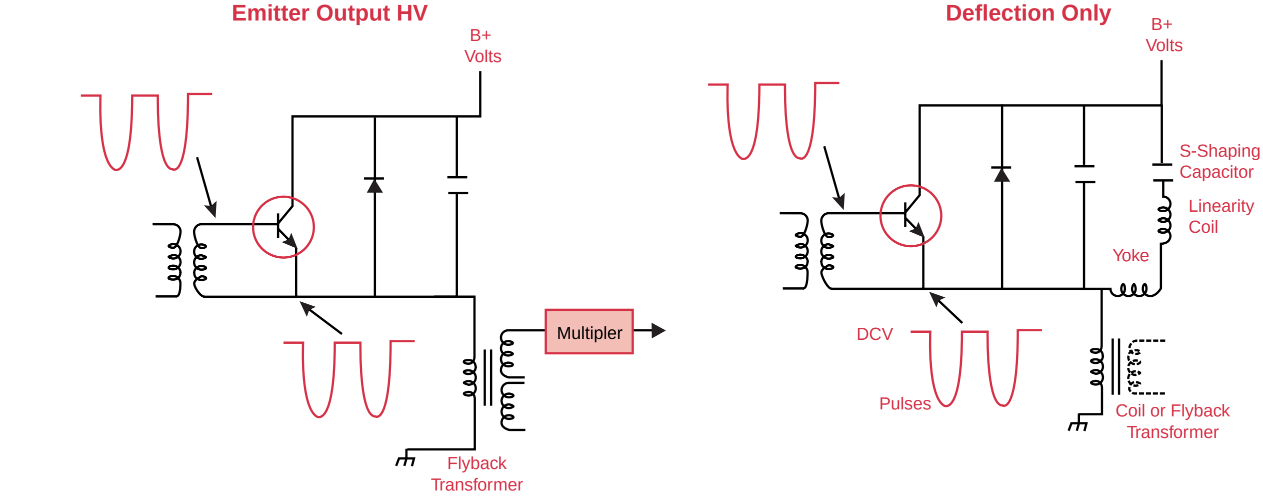

Fig. 7: Typical Emitter Output high voltage or deflection only horizontal output stages.

voltage to the base of the H.O.T. permits a low level of base current enabling the H.O.T. to start conducting flyback primary current. As the current slowly increases in the flyback primary, the base drive transformer induces voltage to the base lead. The voltage draws additional base current enabling the H.O.T. to produce additional collector current. In this manner, the inductive base drive dynamically increases the base current to produce the increasing collector current. The base drive transformer also improves the switching speed to turn the H.O.T. off. This H.O.T. switching method provides more efficient H.O.T. operation reducing its heat and improving stage reliability.

Emitter Output Horizontal Output Stage (HV or Deflection Only)

Most HV or deflection only horizontal output stages include the flyback or energizing coil between the H.O.T.'s collector and the B+ power supply voltage. This produces a voltage or flyback pulse output at the collector or drain of the H.O.T. A rare deviation of this typical horizontal output stage results when the flyback or coil is placed at the emitter lead of the H.O.T. (See Fig. 7) The emitter outputs current to the flyback or coil, thus an emitter output horizontal output stage. This emitter output configuration can be used as a high voltage or deflection only horizontal output stage or combination horizontal output stage.

The flyback primary or coil winding leads to ground typically through a voltage regulation stage (not shown) which regulates the ground side of the current path. A damper diode and timing capacitor parallel the H.O.T. The yoke and its series components draw energy from Ct to produce deflection.

Operation of an emitter output type horizontal output stage is nearly the same as those with the flyback or coil in the collector lead. However, because the emitter is not grounded and contains the inductive component to ground, DC voltages and flyback induced voltages are developed at the emitter in reference to circuit ground. For this reason, the stage's output is seemingly at the emitter of the H.O.T.

To better understand the emitter output, consider the horizontal cycle. During the conduction time of the horizontal output transistor, the emitter is effectively connected to the B+ supply voltage at the collector. Current flows through the flyback or coil winding to energize the stage. When the transistor is switched opened, the coil's magnetic field collapses producing current to charge Ct. The voltage at the emitter decreases with the induced voltage in the flyback or coil winding as Ct charges. When the magnetic field is fully collapsed, Ct discharges through the flyback or coil winding. This causes the voltage at the emitter to increase or become less negative. The charging and discharging action of Ct results in a negative going induced voltage pulse at the emitter of the H.O.T. in respect to circuit ground.

During damper diode time, the collapsing magnetic field returns energy to the circuit producing current flow though the damper diode. The current charges the B+ power supply capacitor. During damper diode time, the B+ supply voltage is switched to the emitter.

This configuration produces no waveform at the collector of the H.O.T. as it is connected to the B+ supply voltage. A DC voltage measurement at the collector reads the B+ supply voltage. Because of the configuration and switching action of the stage, a DC voltage and waveform at the emitter reflect the normal operation of the stage. Negative going flyback pulses of several hundred volts peak-to-peak are typical. The DC voltage at the emitter reflects the B+ supply voltage to the output stage. This is determined by a regulation stage typically along the ground current path on the input side of the flyback or coil.

For More Information,
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