AN-750
Application Note

A SELF-REGULATING HORIZONTAL SCAN SYSTEM

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This application note presents a self-regulating TV horizontal system featuring high performance with efficient operation. A horizontal output protective circuit is also discussed.

MOTOROLA Semiconductor Products Inc.

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INTRODUCTION

Many television designs use an off-the-line power supply (hot chassis) to power their television receivers. This technique is an obvious approach to keeping the number and cost of components down. However, one disadvantage of this approach is the poor scan regulation with beam current modulation and line voltage variation. This note will review some fundamentals of an inexpensive self-regulating scan system for television. It will also introduce a different concept for short-circuit protection, and discuss some important parameters to be considered in reliable scan designs.

BRIEF DESCRIPTION OF A BASIC HORIZONTAL OUTPUT CIRCUIT

The basic television horizontal output system is shown in Figure 1. It is divided into three parts with each part representing a certain segment of the horizontal line time period. Figure 2 shows the various current and voltage waveforms encountered in the horizontal circuit. The current probes were inserted as shown in Figure 1A.

The base current is used as the starting point. Figure 1A shows the base current flowing and the resultant collector current path. The collector current flows through the flyback and yoke coils with a ramp waveshape as shown in Figure 2. If the flyback and yoke current were summed together, they would equal the collector current. The maximum level the collector current will reach is determined by the B+ voltage, the parallel inductance value of the flyback/yoke coils, and the amount of time the horizontal output transistor is switched on. This amount of on time is approximately 45% of the total horizontal line period. About 20% of the remaining time occurs during the retrace period. This retrace period occurs immediately after the collector current has been turned off, which was initiated by the reversal of the base current as shown in Figure 1B. During the retrace interval, the flyback and yoke stored emf charges the retrace capacitor to a very high voltage potential. The capacitor, once fully charged, then resonates with the flyback and yoke coils, but is damped in the reverse direction by the damper rectifier. The damper rectifier conducts the reverse flyback and yoke emf for the remaining 35% of the horizontal line period. As shown in Figure 2, the horizontal yoke sweeps the CRT electron beam from left to right and back again. The peak-to-peak amplitude of the yoke current determines the angle the electron beam will be deflected,

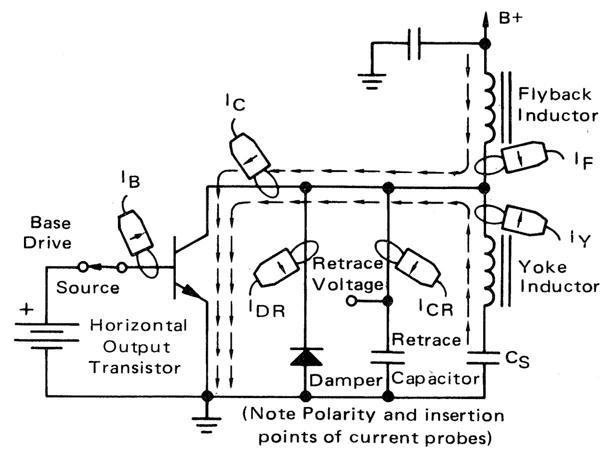

FIGURE 1A – Current Flow During Time Period T1

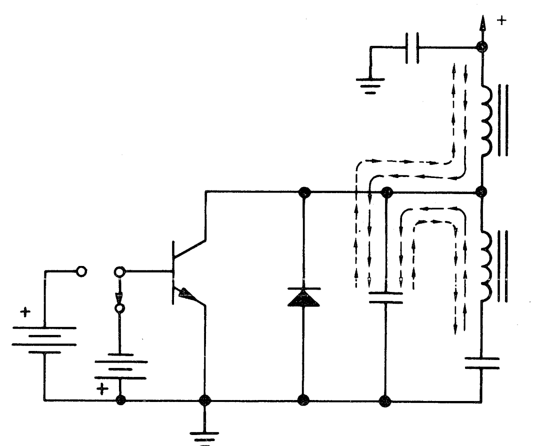

FIGURE 1B – Current Flow During Time Period T2

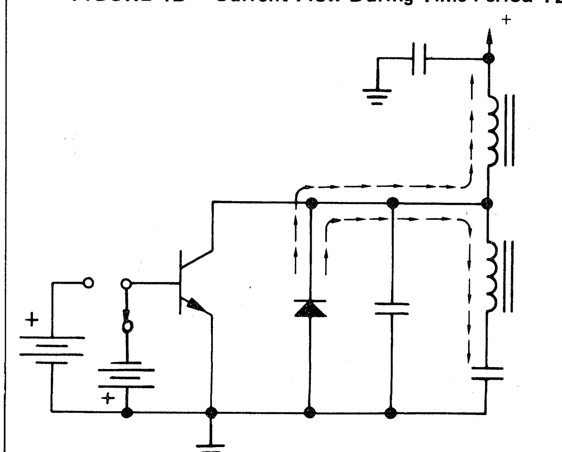

FIGURE 1C – Current Flow During Time Period T3

FIGURE 1 – Basic Horizontal Output Circuit

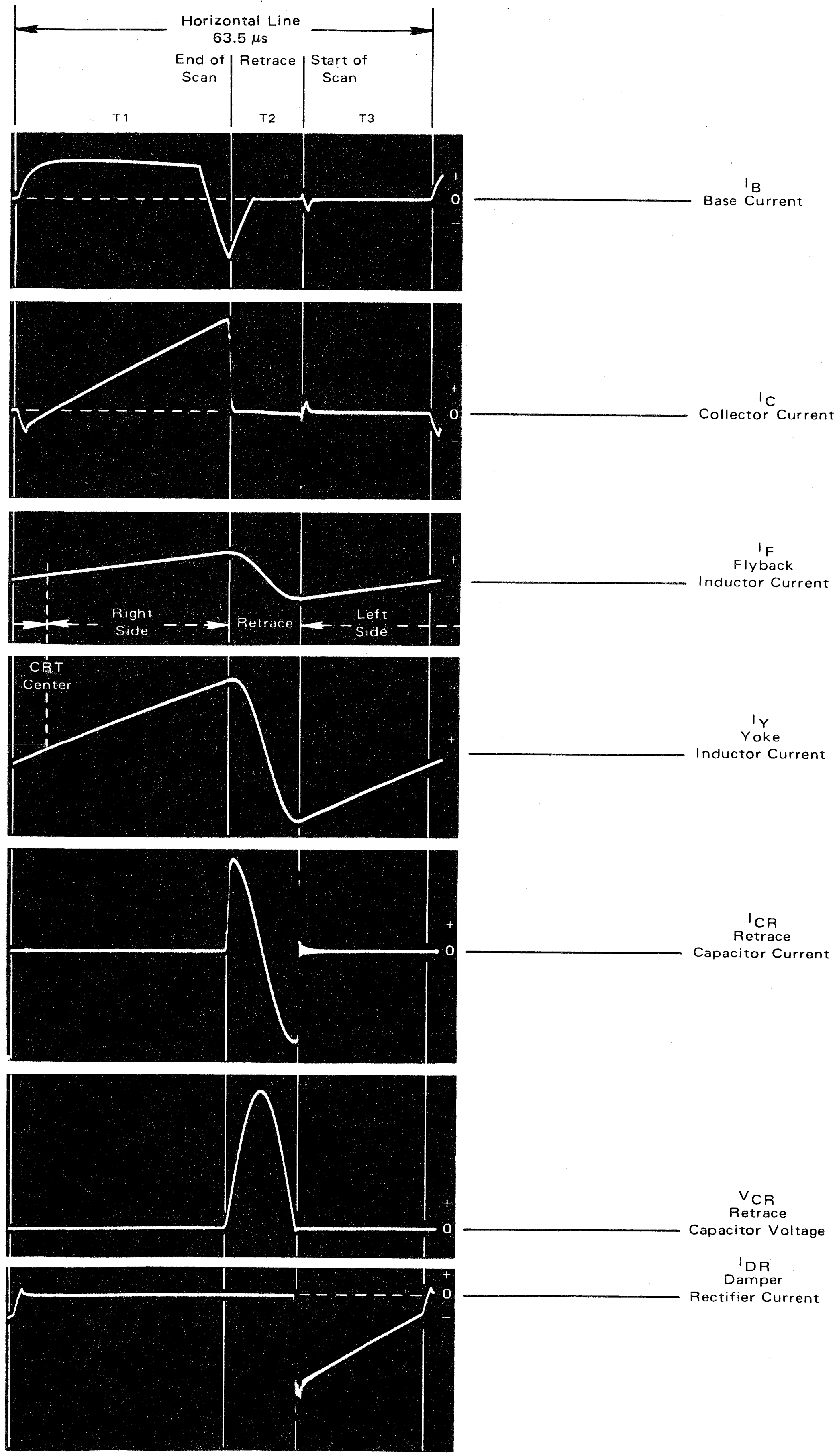

FIGURE 2 — Basic Horizontal Output Waveforms

and is dependent upon the CRT neck size, yoke inductance, and high voltage of the system.

BASIC SELF-REGULATING HORIZONTAL CIRCUIT

By injecting a controlled amount of additional current into the retrace capacitor (C_R) during the retrace time period, the basic horizontal system can be made self-regulating. This stabilizes the average voltage on C_R, and hence also on C_S, which is the "effective" source for the deflection process. A circuit to inject current into the retrace capacitor C_R is shown in Figure 3A, the circuit has three modes of operation, shown in Figures 3A, 3B, and 3C. Each figure shows the current flow for a portion of the horizontal line period as shown in Figure 4 photos. Figure 3A indicates the current flow during the time the base current is turned on. C_S was charged from the previous cycle, and therefore discharges through L_{FY}, D_T and the output transistor. This portion of the horizontal waveform is similar to the basic horizontal circuit waveform shown in Figure 2, with the exception of the supply primary transformer current shown in Figure 3A. Figure 4A displays waveforms from the circuit in Figure 3A, at a B+ voltage level of 130 V. Figure 4B shows the effect when the B+ voltage is raised to 175 V. Figure 5A was taken with a minimum high voltage load at a nominal B+ of 145 V. As seen in Figure 5B, the input transformer's current increases when the high voltage load increases. Input transformer TI has a 1-to-1 turns ratio and couples the primary emf into the secondary winding. This occurs right after the transistor turns off. The losses from the flyback transformer's external loads (CRT HV, auxiliary voltages, etc.) causes the retrace voltage to be less than the voltage generated by the input supply transformer's secondary and therefore, rectifier D_S conducts the voltage difference, which charges C_R up to a desired level that stabilizes the yoke current. As stated previously, the horizontal output transistor is conducting only 45% of the horizontal line period in a typical horizontal system, with approximately 35% of time remaining that the transistor could conduct if it does so in a manner as not to interfere with the yoke current waveshape. By using the input supply transformer connected as in Figure 3A, this is accomplished. The transistor has to be on for at least 45% of the horizontal line period for sufficient yoke current energy.

The remaining 35% can be varied to adjust for changing flyback load conditions or B+ voltage input variations. This 35% of time is varied by changing the duty cycle of the base current pulse as shown in Figure 4. Figure 6 also shows that the amount of duty cycle change is determined by an error amplifier and reference voltage using a feedback signal from the C_S capacitor. By keeping the C_S feedback voltage constant, the flyback and yoke current can be stabilized. An MC1391 horizontal processor device is used for the horizontal oscillator, and duty cycle control. This device was originally designed for the basic type horizontal system application, but is easily used in the self-regulating system. An externally controlled pulse width is one of the features of the MC1391, and is utilized to control the self-regulating horizontal system. By decreasing the voltage on Pin 8 of MC1391, the horizontal output transistor is turned on longer and an increase in Pin 8 voltage reduces the horizontal output transistor on time. An actual working self-regulating circuit description follows.

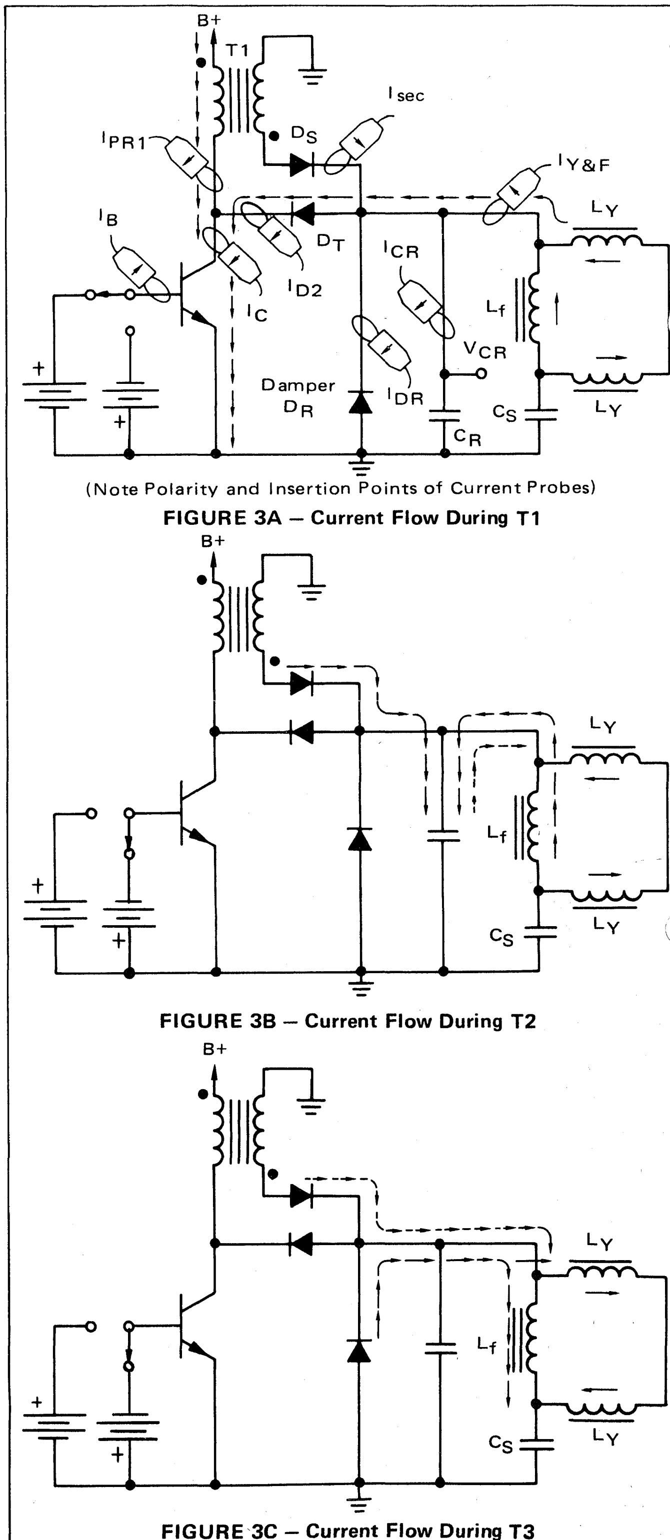

FIGURE 3 – Self-Regulating Horizontal Circuit

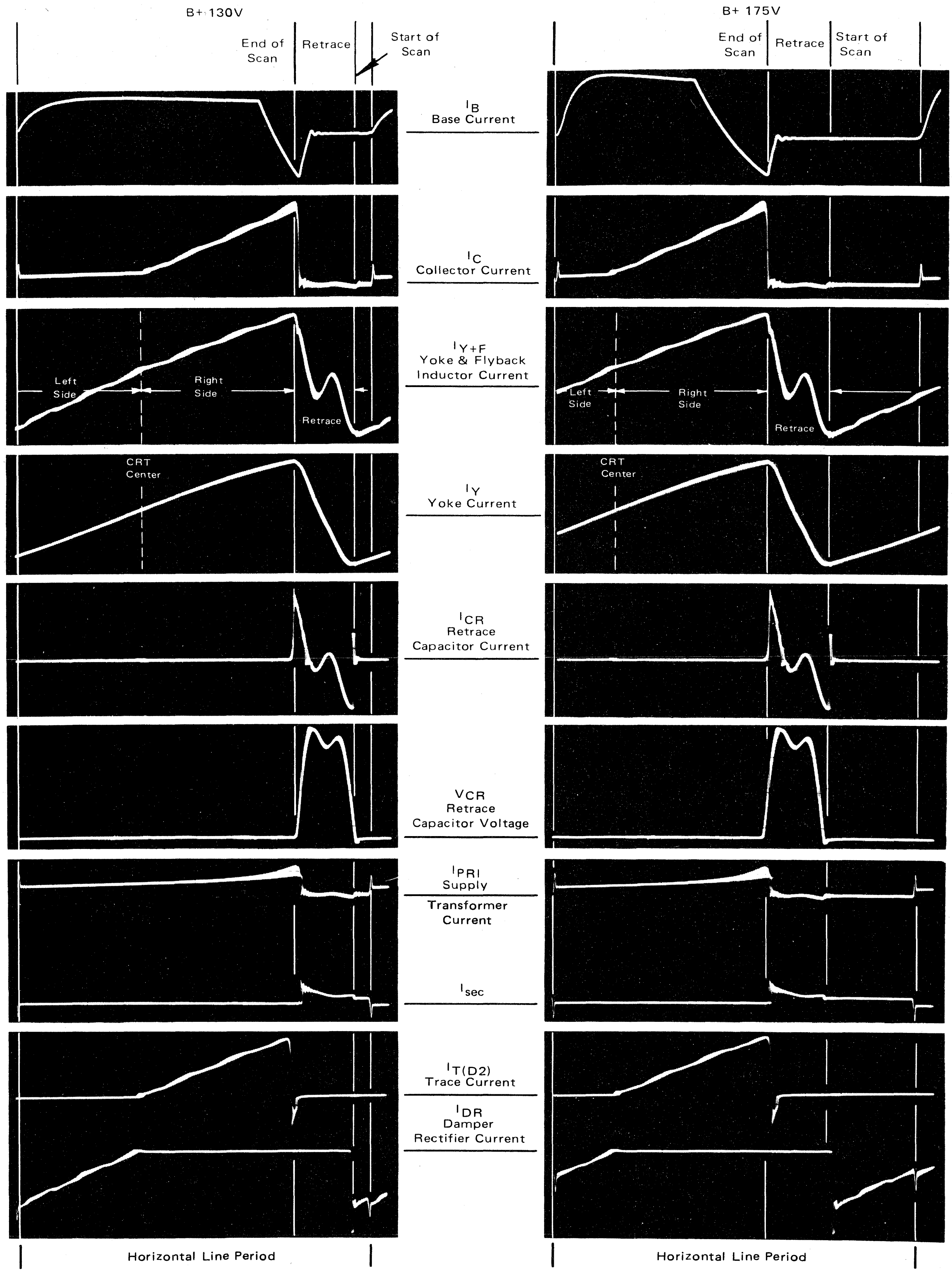

FIGURE 4A

FIGURE 4B

FIGURE 4

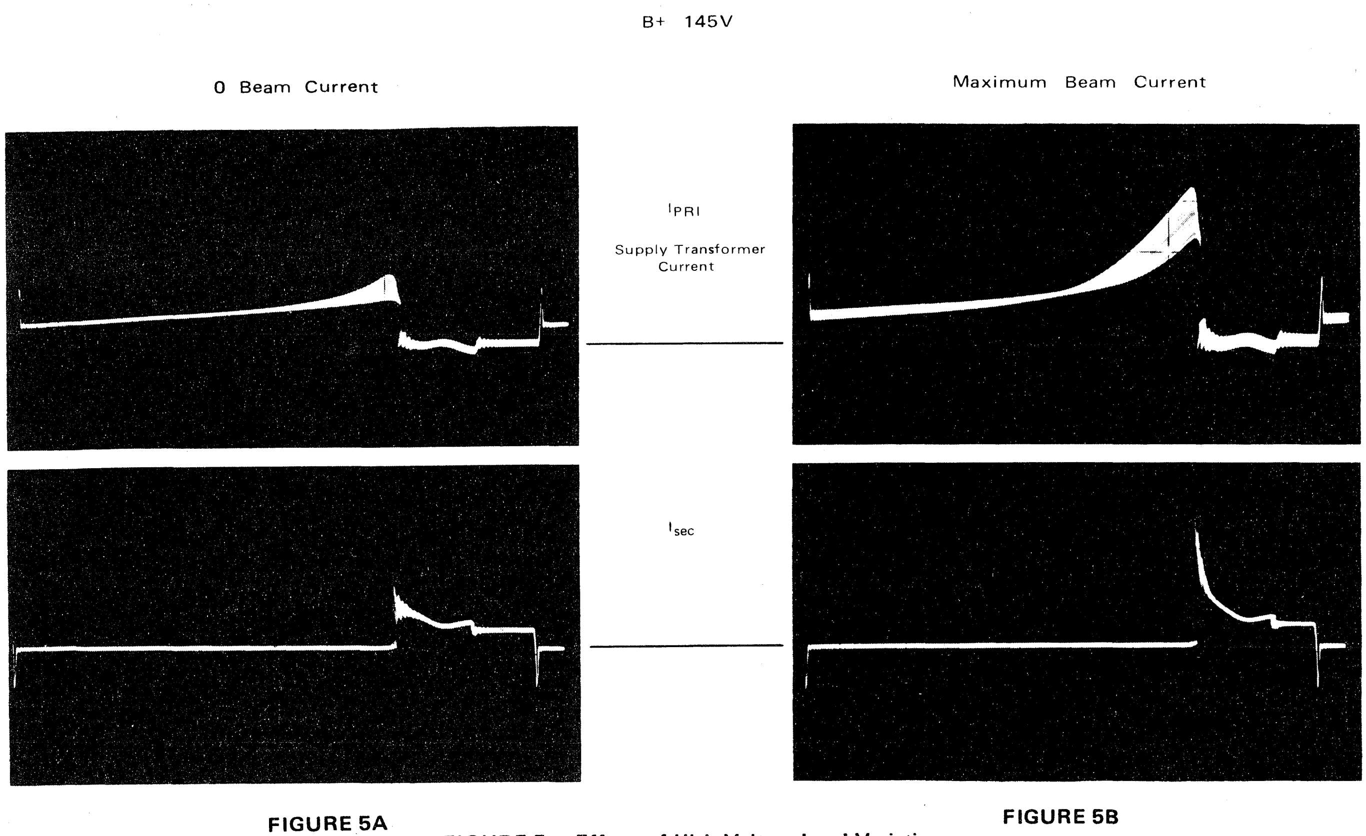

FIGURE 5 — Effects of High Voltage Load Variation

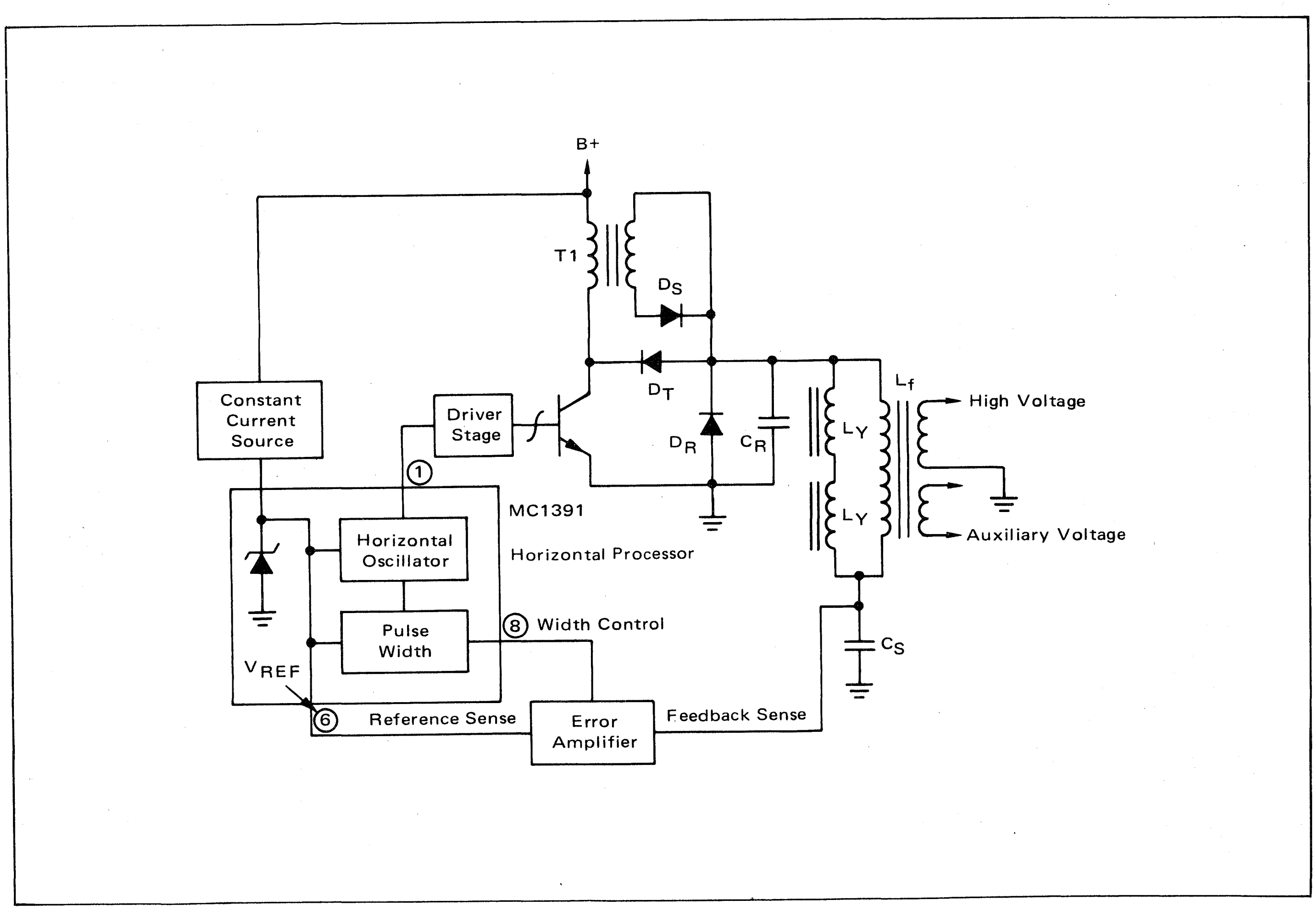

FIGURE 6 — Simplified Horizontal Self-Regulating System

ACTUAL CIRCUIT APPLICATION

A 19" color receiver was chosen to test out the self-regulating horizontal scheme. This particular type of 19" color set employed a half-wave SCR regulated line power supply and used an in-line gun tube with toroidal yokes. Figure 7 displays the horizontal circuit incorporated into the chassis. Figure 8, plotted before the chassis was modified, shows the performance of the conventional horizontal system. Figure 9 shows the improved performance of the horizontal system using the circuit shown in Figure 7. The excellent high-voltage regulation is due in part to the self-regulating circuit and the use of a high-voltage stick or half-wave rectifier. Note that the horizontal yoke current does stay constant, and that the vertical yoke current is also stabilized as it is powered from an auxiliary flyback winding.

The proper choice of the horizontal output switching power transistor is important for the self-regulating concept. The circuit in Figure 6 exhibits a turn on characteristic which requires a minimum dc beta of 5.5 at a collector current level of 8 Amps with V_{CE} of 10 V. If a lower beta device is used, it may fail due to excessive power dissipation.

The importance of the turn-on time (ac power) is that the self-regulating circuit operates the horizontal output switching transistor at a maximum drive pulse width (40 μs) until the horizontal circuit is stabilized at the nominal yoke current. It should be pointed out, however, that the horizontal oscillator circuit (Figure 8) turns on quicker than the output stage and thereby eliminates a potential turn on problem with the horizontal output switching transistor operating in an undefined mode. To provide a safety margin against picture tube arcing, the horizontal output transistor should be rated for a 1400 Volt minimum breakdown voltage in the V_{CEX} mode.

A damper rectifier with quick turn-on time and low power dissipation is beneficial for reliable operation. The device should also be chosen for use in the boost rectifier application and auxiliary flyback voltage source rectifiers. A fast recovery rectifier is required for the auxiliary flyback voltage source supplies, and a 3 A rectifier is used

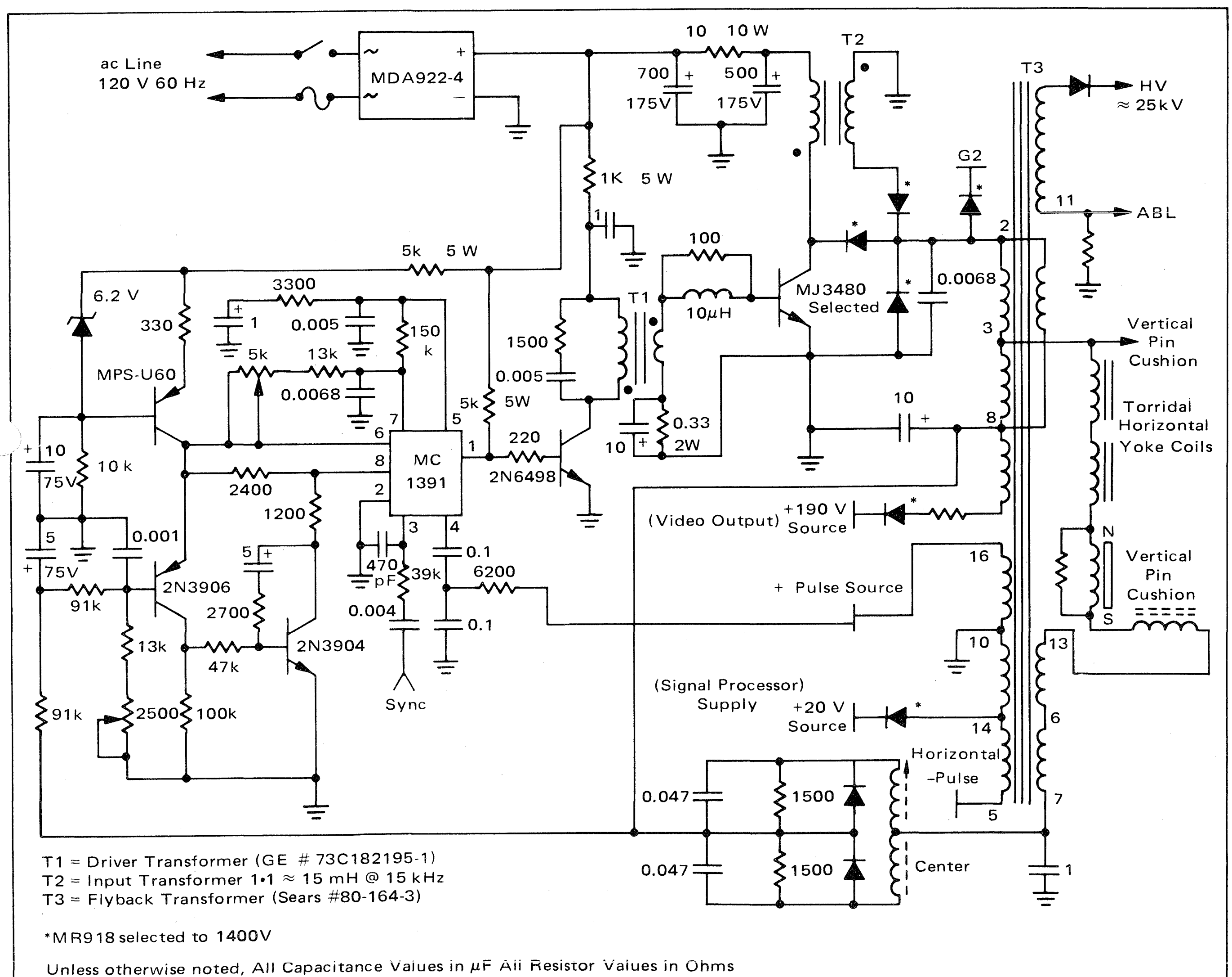

FIGURE 7 — 19" Color Horizontal System Applications Circuit

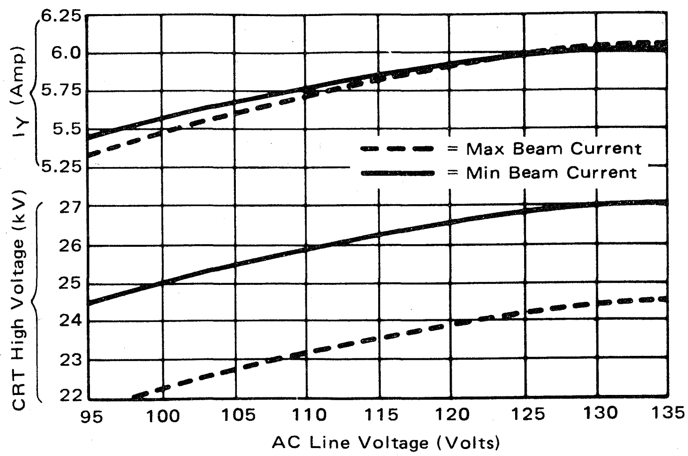

FIGURE 8 — Conventional Horizontal System

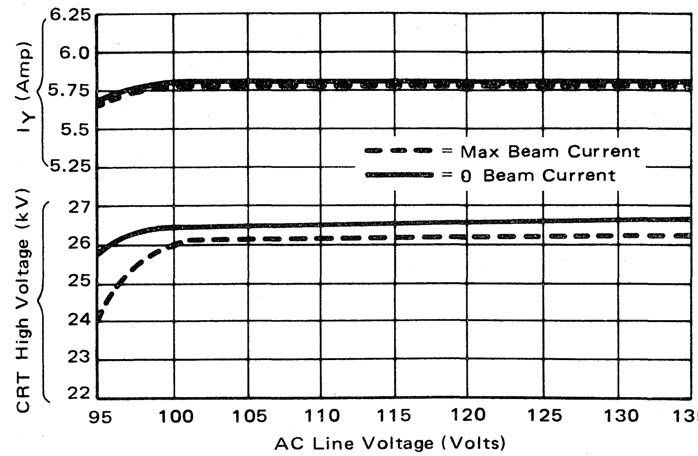

FIGURE 9 — Self-Regulating Horizontal System

because of the high peak currents encountered. An MR918 selected to 1400 V V_R will fill all these needs and could also be used for the line power supply rectifiers.

The horizontal driver transistor used in the self-regulating system is chosen for the following parameters:

1) Collector-Base Voltage of 400 V
2) $V_{CE(sat)}$ of 1 Volt with I_B @ 0.025 A and I_C of 0.4 A
3) Turn-On and Turn-Off Time of less than 1 μs

in a test circuit similar to the horizontal drive circuit shown in Figure 7.

TV HORIZONTAL PROTECTION CIRCUIT

The standard overload protective device for the horizontal output system is a fuse. The problem is that the fuse typically blows only when the circuit fault has caused serious damage to the horizontal system. One scheme used to protect the horizontal output transistor and associated circuitry is the removal of the horizontal drive pulse by a shutdown latch circuit across the base drive of the horizontal driver transistor, when a horizontal overload condition occurs. This method of shutting off the horizontal output transistor can be very detrimental. A closer look at the electrical operation of the driver transformer reveals that the primary winding is out of phase with the secondary winding. This is done to insure a fast turn-off of the horizontal output transistor. The problem lies in the fact that the typical horizontal driver transformer has a large primary inductance value, and will continue to couple stored emf into the low inductance secondary for several milliseconds after the horizontal driver transistor is latched off. This allows the horizontal output transistor to switch a very high level of collector current, permitting the horizontal retrace voltage pulse to reach abnormal voltage levels and may break down the horizontal output transistor collector base junction. As it is highly desirable to disable the horizontal base drive during an overload condition, the circuit shown in Figure 10 will provide protection against the driver transformer stored emf. The circuit is divided into the basic functions and is self-explanatory.

SUMMARY

This review of a basic television horizontal scan system and the discussion of the self-regulating system provides some ideas for doing a more efficient design. Comparing this system with a system using an SCR half-wave regulated power supply, it was found to consume 30% less power. The horizontal protection circuit provides short-circuit and turn-on surge protection. The protection circuit is adaptable to conventional scan systems. Further investigation of self-regulating scan systems is continuing.

REFERENCES

1. Scott, B.: *Choosing the Values for the Major Components in a Television Horizontal Sweep System,* CER 107, Motorola Semiconductor Products Inc.
2. Wessel, P. L.: A New Horizontal Output Deflection Circuit, *IEEE Transactions BTR,* pp. 177-182, June 1972.
3. Maytum, M. J.: Transistorized Self-Stabilizing Horizontal Deflection System, *IEEE Transactions BTR,* pp. 32-63, February 1974.

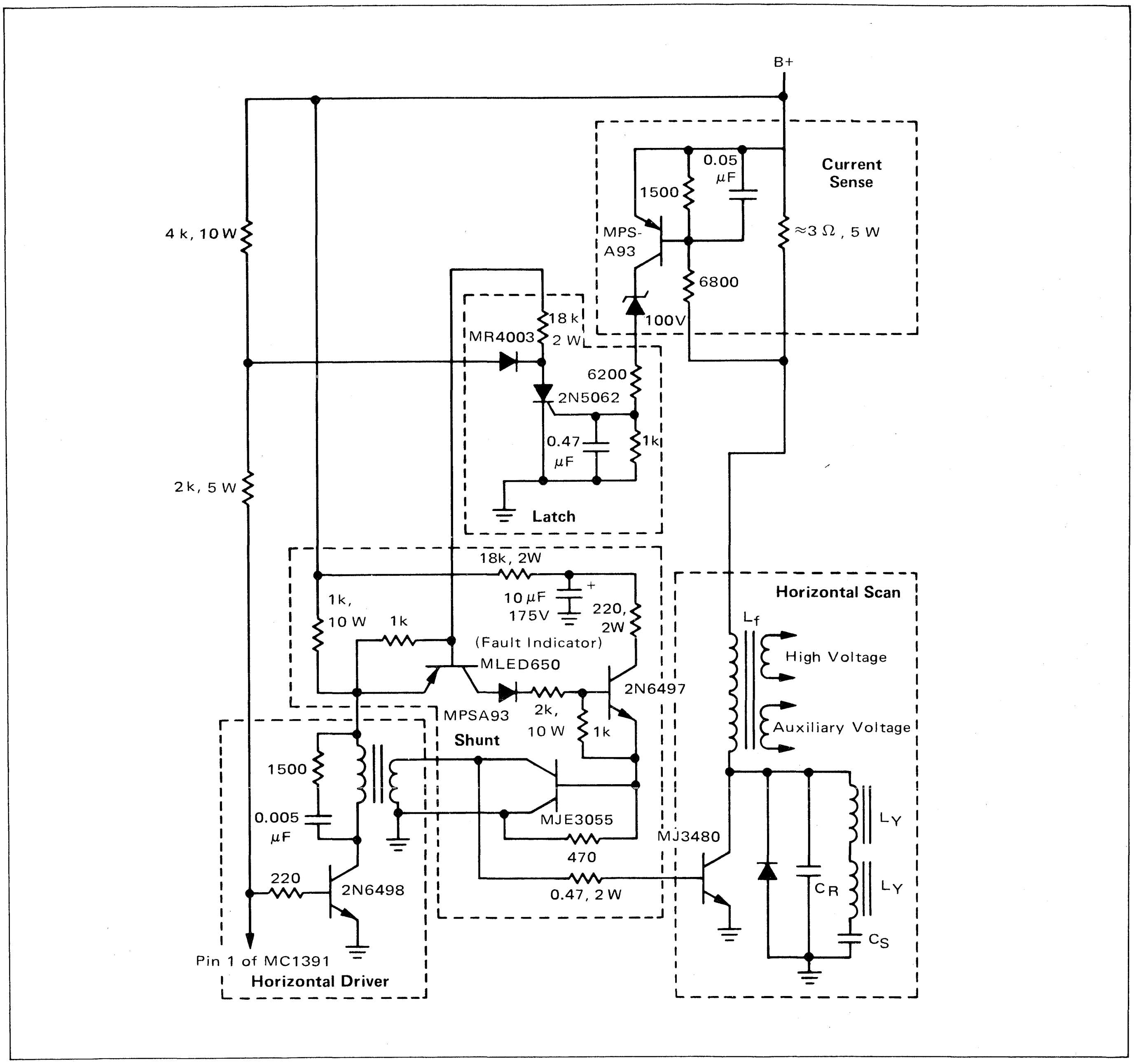

FIGURE 10 — Protective Circuit (Adaptable to Most Horizontal Scan Systems)

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