HEWLETT PACKARD

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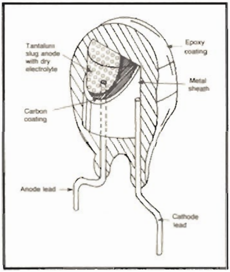
Exploring The Capacitor

What It Is
What It Does
How It Does It



What is a Capacitor?

A capacitor is an electrical component consisting of two metallic conductors called "plates" isolated from each other by a non-conducting dielectric material. This combination is capable of storing electrical energy for later release.

When electrical current flows into a capacitor, a force is established between the two parallel plates separated by the dielectric. In effect, electrons pile up on one plate and their negative charge repels a like number of electrons on the opposite plate. This energy is stored and remains even after the input current flow ceases. Connecting a conductor across the capacitor provides a plate-to-plate path by which the charged capacitor can regain electron balance, that is, discharge its stored energy.

DC THEORY

Figure 1 illustrates how a capacitor is charged by an energy source. If switch S1 is closed and switch S2 is open, current rushes into the capacitor and electrons pile up on one plate, repelling a like number on the other. This means that current will eventually taper off and stop altogether as the capacitor "fills up" with charge (in much the same way as a storage battery).

With both S1 and S2 open, the charge stored in the capacitor will remain there because there is no electrically conductive path between the two isolated plates. When S2 is closed, however, the path is created, and electrons can flow through the load to reach the opposite plate of the capacitor. This flow will continue until the two plates have the same number of electrons at which point the capacitor is said to be *discharged*.

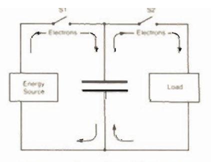


Figure 1. Charging a Capacitor

The amount of charge a capacitor will accumulate is basically determined by the value of the applied voltage and the area of the capacitor plates. A large plate area gives more space for electrons to pile up, increasing the amount of energy storage capability or, more specifically, the *capacitance* of the device. Higher voltage from the charging source allows more electrons to be packed onto the plate.

Of course, a variety of other factors bear strongly on the characteristics of a capacitor. For instance, the capacitance of a capacitor depends upon its internal geometry and the composition of its dielectric. The larger the area of the plates and the closer they are to each other, the higher the capacitance. Then too, the composition of the dielectric separating them also influences the capacitance and frequently gives the capacitor its distinctive name such as paper, mica, ceramic or aluminum. A capacitor using air as a dielectric will increase in capacitance when suitable liquids or solids replace the air in the region between

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the plates (with the plates remaining same size). For example, it will increase perhaps two to five times when oil is used, and about seven times when glass is substituted. Oxide layers that form the dielectric in electrolytic capacitors can produce high capacitances because they have eight to 25 times the dielectric constant of air. Certain ceramics produce a gain of 10,000 or more. What this means in a practical demonstration is that by substituting a better dielectric, the physical size of the capacitor can be reduced while the capacitance remains the same.

How is this capacitance measured? A capacitor has a capacitance of one farad when a one-volt source charges it with one coloumb of electricity, equal to about six million trillion electrons. Since this large unit of capacitance isn't handy to use in practical electrical and electronic circuits, *microfarads* (millionths of a farad, abbreviated μF) or *picofarads* (trillionths of a farad, abbreviated pF), which replaces the old term micro-microfarad ($\mu\mu$F) are used.

AC Theory

When a capacitor is connected to a source of ac voltage, the plates acquire equal and opposite charges that are alternately positive and negative, following the polarity of the alternating voltage source. What results is an alternating flow of electrons in and out of the capacitor terminals (first into plate A and out of plate B, then vice versa as the ac polarity changes). This, in turn, constitutes an ac current flow through the capacitor circuit even though no electron current actually passes through the dielectric material between the plates.

Capacitors exhibit *impedance*, a form of opposition to the flow of alternating current. A capacitor's impedance varies over the frequency range of most applications — the higher the frequency, the lower the impedance, but only up to a point. Impedance also varies inversely with the capacitance. That is, for a given frequency of applied voltage, the higher the capacitance, the lower the impedance.

A capacitor also introduces a phase shift between the applied ac voltage and current in a circuit. To understand this, consider that the current starts at some maximum value and the voltage buildup across the capacitor lags the current, as shown in Figure 2. When the voltage is first applied across the capacitor, virtually no electric pressure is necessary to move electrons on to one plate and away from the other. As the capacitor receives a charge, however, it acquires a voltage polarity which opposes that of the applied source. Also, as free electrons move on the one plate, it will require an increasing voltage pressure to force more onto that plate. Similarly, as electrons are moved away from the other plate, it would require more and more attraction from the positive side of the source to move electrons from an increasingly positive polarity plate. Thus, as shown in Figure 2, the voltage lags behind the current by approximately a quarter cycle or 90°.

Regardless of the capacitor application — filtering, coupling, bypassing, tuning, timing or energy storage — all capacitors store and release energy based on exactly the same principle. Thus, the differences between capacitors types are largely material and manufacturing differences which optimize each type for specific applications.

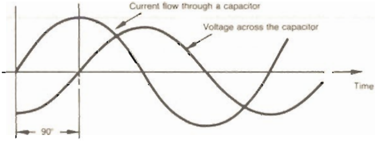


Figure 2. Phase Shift

Editors note: To try and get an idea on just how big a 1.0 farad capacitor would be, I dug out my old Allied handbook and found the following formula:

$$C = 0.224\,\frac{KS(N-1)}{d}$$

where:

C = *capacitance in mmfd*
K = *dielectric constant*
S = *area of one plate in square inches*
N = *number of plates*
d = *thickness of the dielectric in inches*

and:

K = *1.0 (dielectric constant of air)*
N = 2
d = *108 inches (e.g. a 9-foot ceiling)*

The problem becomes an exercise in keeping track of decimal points and powers of ten. I couldn't believe the answer I got so I worked the problem several times. Can you imagine a capacitor with two plates 9 feet apart 346 miles by 346 miles?

Usage, Variety and Internal Construction

The uses made of capacitors become more varied and more specialized each year. They are used to filter, tune, couple, block dc, pass ac, shift phase, bypass, feed thru, compensate, store energy, isolate, suppress noise and start motors among other things. While doing so, they frequently have to withstand adverse conditions like shock, vibration, salt spray, extreme temperatures, altitude, humidity and radiation. They must also be small, light-weight and reliable.

Much research work has been done over the past decade to develop better manufacturing processes, uncover new and improved dielectric materials and enhance capacitor characteristics and reliability. Each capacitor has characteristics in common with others, yet each is designed to excel in a specific application.

Capacitors are generally grouped together according to their dielectric material (e.g., aluminum or tantalum) and mechanical configuration (e.g., chip, dipped, molded, bare). An overview of most of the fixed capacitors currently available is presented here.

Film — Film capacitors consist of alternate layers of metal foil and one or more layers of a flexible plastic insulating material in ribbon form rolled up together and encapsulated. The metal foil may either be a separate ribbon (a long narrow strip of foil) or a thin, vaporized layer of metal deposited on the surface of the insulating material.

Paper/Oil Filled — These capacitors consist of alternate layers of aluminum and one or more layers of paper in ribbon form which are rolled up together. The paper may be saturated with an oil and the assembly mounted in an oil-filled, hermetically sealed metal case.

Aluminum Electrolytic — These capacitors are made of two aluminum foil ribbons rolled up with a porous separator in which a fluid, gel or paste electrolyte is suspended (see Figure 3). One foil is the positive plate (anode), the electrolyte is the negative plate (cathode), the second aluminum ribbon is the cathode contact foil. The dielectric material is a thin non-conductive layer of aluminum oxide formed on the surface of the positive foil by electrochemical action — by connecting the capacitor foil to a dc voltage source for a period of time during manufacturing. This is called *forming* the capacitor. The thickness of this oxide-coated dielectric is determined by the voltage used to form it and the capacitor's working voltage is somewhat less than this formation voltage. Thin films result in low-voltage, high-capacitance units and thicker films produce higher voltage, lower capacitance units for a given case size.

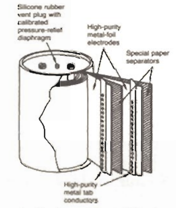


Figure 3. Aluminum Electrolytic Capacitor

The aluminum-foil surface area can be increased by an electrochemical process called *etching* to offer a more effective surface area per square inch of original foil than plain-foil types as well as much higher capacitance for a given volume. For high-capacitance requirements, electrolytic capacitors provide many times the capacitance for a given size than electrostatic (non-electrolytic) capacitors However, electrolytics are inherently "polarized" — that is, they can be used only with dc voltage of the correct polarity and will act as a short circuit, and probably be destroyed, if used with ac voltage or dc voltage of reversed-polarity.

Non-polar (NP) electrolytics are available for motor-starting and other special applications. They consist of *two* electrolytic capacitors connected "back-to-back" (in series with one reversed in polarity with respect to the other) in a single housing. On each voltage half-cycle, the correctly polarized capacitor limits the charge through the other one, which for the time is a virtual short circuit.

Tantalum Electrolytics — Tantalum electrolytics of the foil type are like aluminum electrolytic capacitors in construction, but use tantalum metal foil instead of aluminum. Solid sintered anode types have the highest capacitance per unit volume. They use a porous tantalum slug as the positive plate (anode) while the dielectric is a thin film of tantalum oxide formed electrochemically on the surface of the tantalum.

Solid-electrolyte tantalums (see Figure 4) consist of solid inorganic material containing no liquids or other volatile constituents. A solid semiconductor is used instead of the liquid or semi-liquid electrolytes. The anode is a porous tantalum pellet pressed, sintered and formed like the wet sintered-anode tantalum capacitor, but the dielectric system is "dry."

Like other electrolytics, tantalums are polarized and can be used only with dc voltage of the correct polarity. They are superior to aluminum

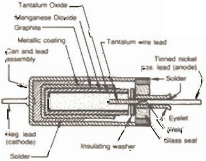


Figure 4. Hermetically Sealed Solid Tantalum Capacitor Construction

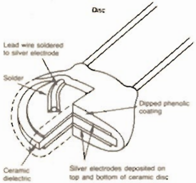
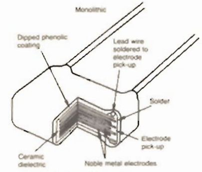


Figure 5. Ceramic Disc Capacitor

electrolytics in operating and storage temperature range, vibration, resistance, leakage and size per microfarad (volumetric efficiency), though their operating voltage range is more limited. Advances in aluminum electrolytic technology, especially the development of non-aqueous electrolytes which contain hydrocarbon fluids instead of water, have reduced the performance differences between aluminum and tantalum electrolytics.

Mica — These capacitors fall into categories. The stacked foil mica capacitor consists of alternate layers of metal foil (or deposited metal film) and sheet-mica insulators which are stacked, compressed and then encapsulated. The silvered mica has a silver electrode material screened on the mica stampings which are then assembled and encapsulated. Glass-fixed capacitors resemble micas, except that silvered ribbons of glass are used, and are fused together to form a solid block.



(Alternately deposited layers of ceramic dielectric material and noble metal electrodes fired into a single homogeneous block.)

Figure 6. Ceramic Monolithic Capacitor

Ceramic — Ceramic capacitors, which come in a variety of sizes, shapes and ratings, are the most popular of the capacitors because of their outstanding versatility. A wide range of dielectric constants can be obtained with different proportions of ceramic mixtures, hence the many different ceramic capacitor types. In addition, the stability of the dielectric constant with respect to temperature is an important feature. In general, the lower the dielectric constant (K), the more stable the capacitance value with temperature variations.

High-K capacitors have a dielectric constant usually in excess of 3000. They are extremely small sized for any given capacitance value and voltage rating. They are used mainly for bypass and coupling, and are usually in the range of 0.001 μF to several μF.

Where greater stability with temperature changes is required, semi-stable and temperature-stable types are used. These will exhibit a capacitance change of less than ±15% or ±5%, respectively, over the operating temperature range.

Temperature-compensating capacitors exhibit controlled and predictable variations in capacitance with temperature changes. They have a dielectric constant of approximately 12 to 200, meaning a larger unit for a given capacitance value, but a high Q, which is required for critical circuit functions such as tuned circuits.

The ceramic capacitors that remain stable despite changes in temperature are called negative-positive-zero (NPO) capacitors. More stable than even the silvered mica capacitors, they are used in many kinds of receivers and generally have values between 1.0 pF and 0.033 ±F.

A commonly used temperature coefficient for temperature-compensating ceramic capacitors is N750. Capacitors with this temperature coefficient have a K of about 90. The 750 means the decrease in capacitance will be 750 parts per million for each degree centigrade of temperature rise. In other words, the capacitance value will decrease 0.075% for a 1°C temperature increase or 1.5% for a 20°C temperature increase. N750 ceramic capacitors are available from about 4.0 pF to about 680 pF and are usually rated at 500 working volts dc.

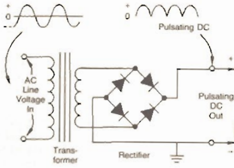


Figure 7.

Capacitor Applications

There are three general applications of the capacitor:

a) As a means of storing and releasing energy.
   1) Filtering out ripple in a dc power supply.
   2) Providing on demand a single high-voltage pulse of current.

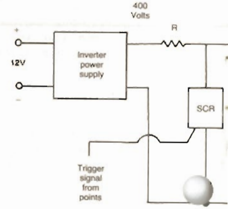
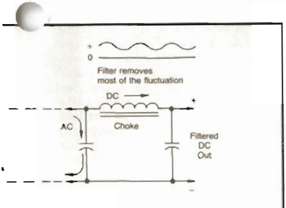


Figure 8. Capacitive



Filtering

b) Discriminating between dc and ac.

1) Bypassing an RF signal around a circuit or component.

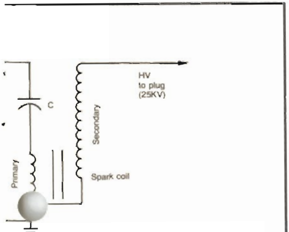
2) Obstructing the dc (Vcc or B+) component of the RF signal in one stage of an amplifier while coupling the RF to the next stage.

c) Discriminating between higher and lower ac frequencies.

1) $f = \frac{1}{2\pi - {}_cC}$ · As the value of C (capacitance) is varied, the resonance frequency of the circuit changes.

Filtering — DC power supplies receive input power from some type of an ac source. The ac voltage is rectified, producing pulsating dc as shown in Figure 7. This pulsating dc is normally unsuitable for powering circuitry, so it must be "smoothed" to eliminate the voltage variations. This is done by a "capacitor input" filter comprised usually of two capacitors and an inductor. The capacitor simply charges up, absorbing most of the voltage increase when the power line exceeds the capacitor voltage, and then discharges energy to the circuit or load when the power line swings lower. The filtered dc output is almost free of annoying ripple. Ripple suppression can be further refined by some kind of electronic voltage regulator. This absorbs virtually all of the variations in applied dc voltage including ripple, line voltage fluctuations and the sags and surges caused by increases and decreases in the load current drawn.

Energy Storage — In some applications, a brief but high-value pulse of current is required periodically, rather than a continuous current flow. One example, the capacitive-discharge (C-D) ignition system in cars, is illustrated in Figure 8. Here, capacitor C is charged to 400 Vdc through resistor R by the output of an inverter power supply. At a specified time, a silicon-controlled rectifier (SCR) is triggered into conduction by a signal from the ignition breaker points. Instantly, C is connected across the primary winding of the ignition coil, dumping its charge in one brief pulse of current. This pulse is transformed by the ignition coil into a secondary voltage of 25,000 volts that fires a spark plug. After the brief pulse has occurred, the SCR becomes non-conducting and capacitor C recharges in preparation for the next firing.



Discharge System

Bypassing — The bypass capacitor is used primarily to keep ac voltages (noise) out of portions of a circuit where they are not wanted. For example, capacitors C1 and C2 in Figure 9A perform two different kinds of bypass functions. In the first operation, the direct current flowing in resistor R1 develops a "bias" voltage that keeps the transistor at the proper voltage level for amplifying radio-frequency signals. If the amplified signal current was also allowed to flow in R1, the dc bias would vary with the signal frequency, greatly reducing amplification. However, C1 connected in parallel with R1 provides a low-impedance path for the RF signal which prevents loss of amplification without affecting the dc bias voltage.

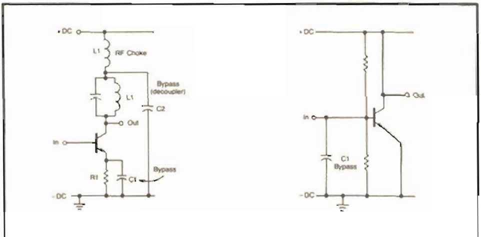


Figure 9. Bypass Functions

In the second operation, C2 forms an RF bypass to ground around the amplifier circuit. This keeps the RF signal from flowing back into the dc power supply, and prevents other RF signals that might already be on the dc line from reaching the amplifier stage.

In the audio amplifier of Figure 9B, capacitor C1 is a relatively high impedance to audio-frequency signals However, RF signals are bypassed to ground

Coupling — a capacitor, once it is charged, is essentially an open circuit to dc. Therefore, as shown in Figure 10 Point X may measure an average of six volts, yet the proper operating level at the base of transistor Q2 (point Y) may be only two volts. The capacitor permits this difference in dc levels, coupling only the ac signals to Q2.

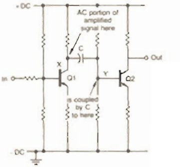


Figure 10. Coupling

Tuning — A capacitor connected in series or parallel with an inductor forms a tuned circuit. At a specific frequency of applied ac voltage (resonant frequency), the circuit is neither capacitive nor inductive, but purely resistive. A series-resonant circuit discriminates sharply against all frequencies except the resonant frequency. A parallel-resonant circuit discriminates sharply against only the resonant frequency. The ratio of the reactance of the circuit at resonance to the resistance in the circuit is the quality factor (Q). The higher the Q is, the sharper the tuning, i.e., the circuit's ability to discriminate against higher and lower frequencies in favor of the resonant frequency. High Q is usually a desirable condition, since if facilitates transmission and reception of communications without interference from transmissions at other frequencies.

Trimming — Trimming is a special case of tuning. A trimmer is connected in parallel with, or in series with, another capacitor (or another circuit component) as shown in Figure 11, permitting the circuit to be fine tuned to resonate at a particular frequency.

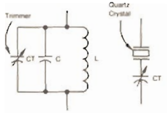
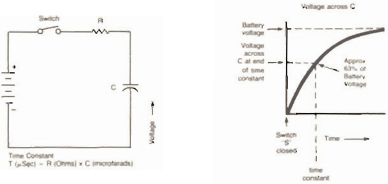


Figure 11. Trimming

Timing — Given a simple timing circuit as shown in Figure 12A, the time it takes the capacitor to reach full charge depends on the values of R and C. Actually, the capacitor never succeeds in becoming fully charged. Accordingly, we calculate the time it takes the capacitor to reach 63% of its full charge value (the battery voltage) and call that the R-C time constant of the circuit. To figure the time in microseconds, multiply the resistance in ohms by the capacitance in microfarads.

Actually, we are more concerned usually with the counter electromotive force built up across the capacitor than the current flowing into it. How this electromotive force is built up is shown graphically in Figure 12B. The time constant, as before, is taken at the point where the counter electromotive force reaches 63% of its full charge value.



Time Constant
T (μSec) = R (Ohms) × C (microfarads)

Figure 12. Timing

Capacitor Terminology and Characteristics

AC Working Voltage — Usually specified at a frequency of 60 Hz. Capacitors are also limited in the "steepness," or speed, of voltage change (usually stated in volts per micro second) to which they can be subjected.

Capacitance — Normally expressed in microfarads (10^{-6} farads) or picofarads (10^{-12} farads) with a stated accuracy or tolerance. Tolerance is expressed as ± (plus or minus) a certain percentage of the nominal or nameplate value. There is also a tolerance rating called GMV, an abbreviation for guaranteed minimum value, sometimes referred to as MRV or minimum rated value, which means that the capacitance is never less than the marked value when used under specified operating conditions, though it may amount to more than the nameplate value.

Capacitance Stability — Usually refers to capacitance variation with respect to temperature change stated in percent change per degree Centigrade. Capacitance can also vary to some extent with frequency and applied voltage, not to speak of time, moisture absorption or chemical and mechanical aging effects. Such changes are governed by capacitor construction and type.

Equivalent Series Resistance (ESR) — A standard characteristic expressed in ohms or milliohms, represents energy losses in the "equivalent" series resistance of a capacitor, regardless of source — lead resistance, termination losses, dissipation in the dielectric material. It assumes that all losses may be represented by a single resistance in series with the "idealized" perfect capacitor.

Insulation Resistance — A measure of the capacitor's ability to retain a charge with time. It is the ratio of the DC voltage applied across the terminals of the capacitor to the DC current flowing through it after the capacitor has charged up to the test voltage. The capacitor then appears as a high resistance in parallel with an ideal (non-leaky) capacitor. Insulation resistance is expressed in megohms for small capacitors and as a time constant (the product of R and C in megohm-microfarads) for higher value capaciors.

Operating Frequency Range — The frequency at which a previously ideal capacitor begins to "look" like a tuned circuit. The capacitor appears to change (increase) in value as the frequency approaches resonance. At still higher frequencies, the inherent inductance dominates and the capacitor actually appears to be inductive, rather than capacitive or resistive. Typically, aluminum electrolytics reach resonance somewhere between 10 kilohertz and 200 kilohertz. Tantalum foil electrolytics resonate between 100 kHz and 200 kHz. Sintered tantalums are usable up to 1 megahertz, and film and paper capacitors are generally usable up to about 30 MHz.

Certain ceramics, micas and glass extend resonance up to 200 MHz. Beyond these frequency limits, capacitor dimensions exert a strong influece on electrical behavior, and the capacitor begins to act like a miniature "transmission line."

Quality Factor (Q) — Dissipation and power factors are also listed with Q (sometimes called Figure of Merit) because they are interrelated. Q is the ratio of the capacitor's reactance to its resistance at a specified frequency. *Dissipation factor* (or DF) is the reciprocal of Quality factor. In other words, DF=1/Q. It is, therefore, a similar indication of power loss within the capacitor and, in general, should be as low as possible. *Power factor* (or PF) represents the fraction of input voltamperes (or power) dissipated in the capacitor dielectric. Virtually independent of the capacitance, applied voltage and frequency, PF is the preferred measurement in describing capacitive losses in AC circuits.

Working Voltage — The maximum voltage at which a capacitor may be continuously operated at rated temperature. When a capacitor's working voltage is specified as a DC value, it includes the total DC plus peak-value AC voltage that may be applied during continuous operation. Electrostatic capacitors can usually withstand an occasional, brief pulse (or surge) beyond this value. Electrolytic capacitors carry a peak (or surge) voltage rating which includes ripple, power-line fluctuation and all transient occurrences. This rating should never be exceeded, even momentarily.

Troubleshooting Capacitors In Solid-State Circuits

Although the functions of capacitors in solid-state circuits are similar to those in vacuum-tube equipment, the results produced by capacitor failure are not necessarily the same. An emitter bypass capacitor is a good example. The emitter resistor in a solid-state circuit (such as R1 in Figure 9A) is used to stabilize the transistor dc gain and prevent thermal runaway. With an emitter resistor in the circuit, any increase in collector current produces a greater drop in voltage across the resistor. When all other factors remain the same, this change in emitter voltage reduces the base-emitter forward-bias differential, thus tending to reduce collector current flow.

When circuit stability is more important than gain, the emitter resistor is not bypassed. When ac or signal gain must be high, the emitter resistance is bypassed to shunt the signal around the resistor. If the emitter bypass capacitor is open, stage gain is reduced drastically, although the transistor dc voltages remain substantially the same.

Thus, if there is a low-gain symptom in any solid-state amplifier with emitter bypass and the voltages appear normal, check the bypass capacitor. This can be done by shunting the bypass with a known good capacitor of the same value. As a precaution, shut off the power before connecting the shunt capacitor; then reapply power. This will prevent damage to the transistor due to large current surges.

The functions of coupling and decoupling capacitors in solid-state circuits are essentially the same as for vacuum-tube equipment. However, the capacitance values are much larger, particularly at low frequencies. Electrolytics are usually required to get the large capacitance values. From a practical standpoint, electrolytics tend to have more leakage than mica or ceramic capacitors. However, good-quality electrolytics (typically the bantam type found in solid-state) will have leakage of less than 10 μA at normal operating voltage.

The function of C in Figure 10 is to pass signals from the previous stage to the base of Q_2. If C is shorted or leaking badly, the voltage from the previous stage is applied to the base of Q_2. This forward-biases Q_2, causing heavy current flow and possible burnout of the transistor. In any event, Q_2 is driven into saturation, and stage gain is reduced. If C is open, there will be little or no change in the voltages at Q_1, but the signal from the previous stage will not appear at the base of Q_2.

From a troubleshooting standpoint, a shorted or leaking C will show up as abnormal voltages (and probably as distortion of the signal waveform). If C is suspected of being shorted or leaky, replace it. An open C will show up as a lack of signal at the base of Q_2, with a normal signal at the previous stage. If an open C is suspected, replace it or try shunting it with a known good capacitor, whichever is convenient.

The function of C2 in Figure 9A is to pass operating signal frequencies to ground (to provide a return path) and to prevent signals from entering the power supply line or other circuits connected to the line. In effect, C_2 and L_1 form a low-pass filter that passes dc and very-low-frequency signals (well below the operation frequency of the circuit) through the power supply line. Higher-frequency signals are passed to ground and do not enter the power supply line.

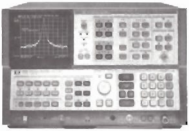
If C_2 is shorted or leaking badly, the power supply voltage will be shorted to ground or greatly reduced. This reduction of collector voltage will make the stage totally inoperative or will reduce the output, depending on the amount of leakage in C_2.

If C_2 is open, there will be little or no change in the voltages at the transistor. However, the signals will appear in the power supply line. Also, signal gain will be reduced and the signal waveform will be distorted. In some cases, at higher signal frequencies, the signal simply cannot pass through the power supply circuits. Since there is no path through an open C_2, the signal will not appear on the collector circuit in any form. From a practical standpoint, the results of an open C_2 will depend on the value of the tuned circuit (and other power supply components) as well as on the signal frequency involved.

Safety-Related Service Notes

Service Notes from HP relating to personal safety and possible equipment damage are of vital importance to our customers. To make you more aware of these important notes, they are printed on paper with a red border, and the service note number has a "-S" suffix. In order to make you immediately aware of any potential safety problems, we are highlighting safety-related service notes here with a brief description of each problem. Also, in order to draw your attention to safety-related service notes on the service note order form at the back of *Bench Briefs* each appropriate number is highlighted by being printed in color.

8568 Spectrum Analyzer



A potential shock hazard may exist on 8568A Spectrum Analyzers with serial prefix 1833A and below. If the A1A8 rectifier assembly is removed from the analyzer while the AC line cords are connected, the +100 Vdc filter capacitor A1A10C1 remains charged creating a shock hazard.

This problem is eliminated by adding a 100 kΩ 0.5w resistor in parallel to the filter capacitor. For more details, order safety service note 8568A-16-S using the order form at the back of *Bench Briefs*.

Please note that there are several more service notes available for the 8568A that provide information on troubleshooting and service tips that improve instrument performance.

Product Safety Service Note Index

M59-1-S is a list of all safety-related instrument service notes issued by Hewlett-Packard. If you own HP equipment, you need this index to determine if your instruments have any outstanding safety service notes issued against them. Please order M59-1-S today!

New Service-oriented Videotapes From HP

HP has two new service-oriented videotapes which should be especially valuable to service personnel. You can order them through your local HP sales or service office, or contact HP Video Products, 1819 Page Mill Road, Palo Alto, CA 94304, (415) 856-2381.

How To Solder (Two Tapes) HP Part No. 90751D

The subject seems simple enough, but a poor solder connection can cause electronic equipment to fail — sometimes outright or worse, intermittently. Either type can be costly in terms of downtime for troubleshooting and repair.

This videotape series is aimed at new hires who will work in manufacturing and service — including those persons who believe they already know how to solder properly. Some of the points covered are: What is soldering, wetting, flux, and tinning? How to:

— Clean parts to be soldered.

— Perform the four basic soldering steps.

— Recognize a good/poor solder connection.

— Unsolder using the vacuum bulb, solder sucker, and desoldering wick.

How To Use An Oscilloscope (Three Tapes) HP Part No. 90741D

The purpose of this 3-tape series is to train technicians in the basic techniques of using an oscilloscope to measure waveforms.

Part 1 uses an HP 1740A general purpose oscilloscope to show single channel measurements and how to:

a) measure the peak-to-peak ac voltage, time period, frequency and dc component (if any) of a waveform;

b) measure low level signals such as power supply ripple;

c) trigger or synchronize the scope to obtain a stable display on the CRT; and

d) avoid errors in control settings that could lead to measurement inaccuracies.

Part 2 uses the same HP 1740A oscilloscope to demonstrate dual channel measurements. You will see how to operate a scope in the dual trace, A + B, A-B, and A versus B modes. Also covered are selectable and composite triggering, trigger view mode, bandwidth limit and delayed sweep operation.

Part 3 completes the series. It shows you how to check your scope and probe to make sure they are operating properly. You'll see that one probe cannot be used for all measurements, so the three types of commonly available voltage probes are covered. Then you will see how to make some typical oscilloscope voltage and time measurements. Finally, storage scopes are covered. An HP 1741A storage oscilloscope is used to show you how to solve the problem of viewing low rep-rate signals and one-shot events. The program ends with a short summary.

All programs are supplied on 3/4" videocassettes for Sony U-matic equipment and compatible makes. Other formats will be quoted on request, such as: 1/2" EIAJ-1 reel-to-reel, and Betamax.

BENCH BRIEFS INDEX

Need Any Service Notes?

Here's the latest listing of Service Notes available for Hewlett-Packard products. To obtain information for instruments you own, remove the order form and mail it to the HP distribution center nearest you.

GENERAL

M-48A. All serials. Cleaning Autogrip Tables on HP X-Y Recorders.
M59-1-S. Product Safety Service Note Index
5083-5. All serials. Recommended Replacement Procedures for Rectangular Storage CRTs.

180A/AR OSCILLOSCOPES

180A/AR-11. All serials. Modification to improve +100V power supply stability.

180C/D OSCILLOSCOPES

180C/D-3. All serials. Modification to improve +100V power supply stability.

180T/TR OSCILLOSCOPES

180T/TR-1. All serials. Modification to improve +100V power supply stability.

181A/AR OSCILLOSCOPES

181A/AR-9. All serials. Modification to improve +100V power supply stability.

181T/TR OSCILLOSCOPES

181T/TR-1. All serials. Modification to improve +100V power supply stability.

182A/C OSCILLOSCOPES

182A/C-2. All serials. Modification to improve +100V power supply stability.

182T OSCILLOSCOPES

182T-1. All serials. Modification to improve +100V power supply stability.

184A/B OSCILLOSCOPES

184A/B-3. All serials. Modification to improve +100V power supply stability.

214B PULSE GENERATOR

214B-1. Serials 1718G00189 and below. Recommended VMOS power FET replacement and protection.

1332A DISPLAY

1332A-9. All serials. Preferred replacement for A2R90 Astigmatism Potentiometer.

1333A DISPLAY

1333A-3. All serials. Preferred replacement for A2R90 Astigmatism Potentiometer

1335A DISPLAY

1335A-5. All serials. Recommended modification to improve CRT performance.
1335A-6. All serials. Preferred replacement for A2R90 Astigmatism Potentiometer.
1335A-7. Recommended CRT uniformity/writing speed optimization adjustments.

1336A DISPLAY

1336A-1. All serials. Recommended instructions for removal & return of CRT timer.

1350A GRAPHICS TRANSLATOR

1350A-2. Serials 1750A and below. Recommended modification to improve initialization response to HP-IB Interface Clear (IFC).
1350A-3. Serials 1906A and below. Recommended programming aid for HP-IB controllers.

1611A LOGIC STATE ANALYZER

1611A-8. Serials 1837A01345 and below. Recommended modification to eliminate bright spot on CRT after turn off.
1611A-9. All serials. Preferred cable replacement for microprocessor probe and external probe.

1615A LOGIC ANALYZER

1615A-1. Serials below 1905A-1750. Recommended modification to eliminate bright spot on CRT after turn off.

1640A SERIAL DATA ANALYZER

1640A-4. Serials 1845A00532 and below. Recommended modification to eliminate bright spot on CRT after turn off.
1640A-5. Serials 1825A and below. Recommended replacement procedures for CRT faceplate.
1640A-6. Serials 1845A00549 and below. Recommended replacement of Zenier Diode A2CR4

1715A OSCILLOSCOPES

1715A-4. All serials. Recommended modification to eliminate vertical oscillations.

1741A OSCILLOSCOPE

1741A-8. Serials 1812A and below. Recommended replacement kit to reduce blooming.

3325A SYNTHESIZER/ FUNCTION GENERATOR

3325A-2. Serials 1748A00231-1748A00425. Recommended modification to prevent early failure of the K1 relay.

3490A MULTIMETER

3490A-16. Serials 1637A06200 and below. Recommended modification to improve reliability of the A2 high impedance assembly.

3495A SCANNER

3495A-5. Serials 1428A03935 and below. Recommended procedures for Gordos relay installation.

3720A SPECTRUM DISPLAY

3720A-4. Serials 1534U-00320 and below. Recommended replacement for A20Q5.

3743A IF AMPLIFIER

3743A-1. Serials below 1734U-00101. Recommended field replacement of A2MC1

3745A/B SELECTIVE LEVEL MEASURING SET

3745A/B-4D. Serials 1607U and below. Recommended procedures to eliminate HP-IB system operational errors.
3745A/B-22A. All serials. Recommended replacement of A109 ROM4.
3745A/B-25A. All serials. Recommended replacement of 256-bit shift registers on XY Driver A601.
3745A/B-28. Serials 1908U and below. Recommended procedures to suppress 10MHz & 20MHz spurious signals.
3745A/B-29. Serials 1908U and below (options 050, H15 & H29). Modification to improve performance of A109 memory assembly.

3747A/B SELECTIVE LEVEL MEASURING SET

3747A/B-4. All serials. Preferred replacement of A109 ROM4.
3747A/B-6. All serials. Preferred replacement of A319A1C2.
3747A/B-7A. All serials. Recommended replacement of 256-bit shift registers on XY Driver A601.

3770B TELEPHONE LINE ANALYZER

3770B-17A. Serials below 1851U-00380. Recommended modification to improve performance of Power Supply.
3770B-18. Serials below 1851U-00361. Recommended modification to A31 Input Amplifier assembly.

3771A DATA LINE ANALYZER

3771A-2. All serials. Recommended procedures for retrofitting for option 001 (+10dBm switch).

3771A/B DATA LINE ANALYZER

3771A/B-3. Serials below 1806U-00114 (3771B) and 1806U-00119 (3771A). Recommended modification to assembly A33.

3779A PRIMARY MULTIPLEX ANALYZER

3779A-1. Serials from 1832U-00101 to 1832U-00105, 1840U-00106 to 1840U-00109 inclusive, 1903U-00111 to 1903U-00115 and 1903U-00120. Recommended modification to improve performance.
3779A-2. Serials 1840U-00110 and below. Recommended procedure to improve performance.
3779A-3. Serials 1840U-00110 and below. Recommended modification to Transmitter QD Filter.
3779A-4. Serials 1904U-00135 and below. Recommended modification to Digital Receiver Clock Extraction circuit.
3779A-6. Serials 1909U-00145 and below. Recommended adjustment to the 12Hz and 40Hz Selective Filters.
3779A-7. Serials 1909U-00145 and below. Recommended modification to improve performance of self-test.

3779B PRIMARY MULTIPLEX ANALYZER

3779B-1. Serials 1832U-00101 to 1832U-00105, 1840U-00106 to 1840U-00110 inclusive, and 1903U-00111 to 1903U-00116. Recommended modification to improve performance.
3779B-2. Serials 1840U-00110 and below. Recommended modification to improve performance. Failure code S71 or S72 during "basic analog" self-test.
3779B-3. Serials 1840U-00110 and below. Recommended modification to improve performance.
3779B-4. Serials 1904U-00135 and below. Recommended modification to improve performance.
3779B-5. Serials 1909U-00145 and below. Recommended replacement parts for A24012 & A24022.
3779B-6. Serials 1909U-00145 and below. Recommended modification to the 12Hz and 40Hz Selective Filters.

3780A PATTERN GENERATOR/ ERROR DETECTOR

3780A-10C. Serials below 1804U-00531. Recommended modification to reduce susceptibility to conducted mains supply interference.
3780A-19. Serials 1810U to 1920U inc. Recommended modification to improve performance.

4940A TRANSMISSION IMPAIRMENT MEASURING SET (TIMS)

4940A-13A. Serials 1401A-01234 and below. Recommended modification to improve power supply reliability.

5045A DIGITAL I.C. TESTER

5045A-14. Serials 1852A-00346 and below. Recommended 4 MHz clock modification.
5045A-16. Serials 1852-00356 and below. Recommended A11 Reference Level Generator modification to improve DAC settling time.

5301A 10 MHz COUNTER

5301A-1. Serials 1824A04926 to 1824A05275. Recommended modification to improve performance of addressable mode.

5342A MICROWAVE FREQUENCY COUNTER

5342A-10. All serials. Recommended procedure for replacing low frequency input fuse.

5342A-11. All serials. Recommended procedure for replacing ground fingers on Assemblies A4, A5, and A8.

5342A-12. All serials. Information to aid in troubleshooting A3, A4, A5, A6, A7, A8, A9, A11, A12, A13, A14, A25, and A26 assemblies.

5420A DIGITAL SIGNAL ANALYZER

5420A-17. 5443A keyboard/control. Serials 1836 and above. Test procedure to detect parity error/memory loss indications.

5420A-18/54451C-02. Series 1836 and below. Modification to improve handshake.

5420A-19. 5443A keyboard/control. All serials. Recommended replacement parts to improve Booster Board performance.

6825A, 6826A, 6827A
DC POWER SUPPLY AMPLIFIERS

6825A-1/6826A-1/6827A-1. All serials. Recommended procedure to prepare the unit for rack mounting.

7221A GRAPHIC PLOTTERS AND SERVICE KITS

7221A-7. Serials 1823A01350 through 1823A01450. Recommended procedure for replacing jumper on RS232 PCA.

8405A VECTOR VOLTMETER

8405A-7. All serials. Recommended replacement kit for A3/A4 Sampler Board Assembly.

8412A PHASE-MAGNITUDE DISPLAY

8412A-8A. All serials. Recommended replacement for A3U1, A3U3, and A3U4 BI-FET Analog Switches.

8565A SPECTRUM ANALYZER

8565A-5A. All serials. YTO Replacement Kit, HP P/N 08565-60161.

8568A SPECTRUM ANALYZER

8568A-7A. Serials 1837A00360 and below. Recommended modification to reduce residual responses.

8568A-8. All serials. Recommended new sweep time accuracy performance test.

8568A-10. Serials 1837A and below. Recommended use of A14 signature analysis diagram for troubleshooting.

8568A-13. Serials 1828A and below. Recommended improvements to improve performance.

8568A-14. Serials 1852A and below. Recommended modification to improve A12 RF Section Interface/A5K1 Input Relay compatibility.

8568A-15. Serials 1839A and below. Modification to improve performance in 50 to 300 MHz range.

8568A-16-S. Serials 1833A and below. Elimination of potential safety hazard.

8568A-17. All serials. 75Ω Option (Option 001) A14 Memory assembly recommended modification.

8620C SWEEP OSCILLATOR

8620C-3. All serials. Recommended modification to improve performance.

8660B SYNTHESIZED SIGNAL GENERATOR

8660B-33. All serials. Recommended modification of A1A3 operation on extender board.

8660C-9. All serials. Modification to improve performance of A1A3 operation on extender board.

8750A STORAGE-NORMALIZER

8750A-4B. Serial 1808A and below. Recommended selected resistor for use with dedicated interface cards. Option 003 and 004.

8750A-7. Serials 1712A and below. Recommended modification to improve penlift timing during retrace.

54451C COMPUTER BASE SYSTEM

5420A-18/54451C-02. Series 1836 and below. Modification to improve handshake.

59403A COMMON CARRIER INTERFACE

59403A-3. Serials 1426A01120 and below. Recommended modification to improve data reliability.

86250A/B RF PLUG-IN

86250A/B-3B. Serials 1238A and below. YTO Replacement Kit, HP P/N 86250-60040 and 86250-60055. Serials 1246A and above. YTO Replacement Kit, HP P/N 86250-60041 and 86250-60071.

How to Eliminate That CRT Bright Spot After Turn-Off

Logic State Analyzers — 1611A's, 1615A's, and 1640A's (1611A shown).

A modification is now available that will eliminate that annoying bright spot that appears on the CRT after turn-off. While the bright spot may darken the phosphor over a period of time, instrument performance or display capability is not adversely affected.

The modification described in service notes 1611A-8, 1615A-1, and 1640A-4 consists of adding a 50 uf capacitor (HP p/n 0180-0141) in parallel with capacitor A3C17 on the display driver board.

For more information, please order the appropriate service notes.

Improve HP-IB Operation of Your 1350A Graphics Translator

Two service notes in this issue of *Bench Briefs* improve the operation of your 1350A translator. 1350A-2 describes a hardware modification to translators with serial prefix 1750A and below. The modification consists of shortening the internal delay associated with IFC initialization.

The second note, 1350A-3, describes a programming aid that will eliminate the multiple colons used to provide necessary delays following a 1350A instruction.

Both of these service notes can be ordered with the service note order form at the back of *Bench Briefs*.

SERVICE NOTE ORDER FORM

If you want service notes, please check the appropriate boxes below and return this form separately to one of the following addresses.

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☐ M-59-1-S
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☐ 180C/D-3
☐ 180T/TR-1

☐ 181A/AR-9
☐ 181T/TR-1
☐ 182A/C-2
☐ 182T-1
☐ 184A/B-3

☐ 214B-1
☐ 1332A-9
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☐ 3779A-4
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☐ 5342A-12
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☐ 8568A-15
☐ 8568A-16-S

☐ 8568A-17
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☐ 59403A-3
☐ 86250A/B-3B

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