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How To Build a Stripline Filter

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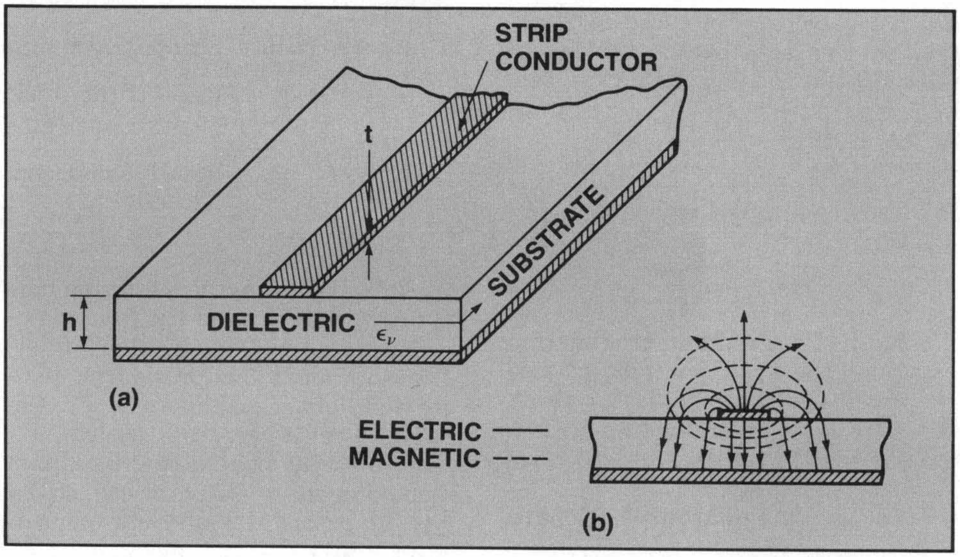

Figure 1. Microstrip is separated from a ground plane by a dielectric substrate (a). Since not all field lines pass through the substrate (b), a quasi-TEM analysis is used.

Introduction

In an earlier issue of *Bench Briefs,* John Kristiansen described the mechanical steps required to fabricate RF breadboard circuits with copper tape. In this article, John will show you how to apply those same principles of fabrication, combined with a few basic microwave formulas, to construct a microstrip bandpass filter using parallel resonators made of copper tape. If you desire a more accurate filter, you can use the same principles presented in this article to design a filter etched on a pc board.

Since we are now dealing with microwave frequencies above 0.5 GHz, this article assumes that the reader has a fair amount of knowledge in microwave and microwave instrumentation.

Fundamental Concepts

Let me start out by defining what I mean by a microstrip transmission line. A microstrip (see Figure 1) transmission line consists of a strip conductor and a ground plane separated by a dielectric medium. The dielectric material serves as a structural substrate upon which the thin-film metal conductors are deposited. Conductors are usually gold or copper. In our case, the metal conductors will actually be the copper tape.

Choosing a Filter Design

An enormous amount of material has been written on microwave filter design. *Ham Radio* magazine has published articles by Jerry Hinshaw, N6JH; Rick Campbell, KK7B; and James Davey, WASNLC. These articles cover interdigital filters, microwave local oscillators using a combination of filter and MMICs, and experiments with microstrip bandpass filters in the range of 2160 to 5780 MHz. There is also an IEEE paper by J. Wong that comes close to a cookbook design of microstrip filters.

The filters that I have experimented with since 1970 are shown in Figure 2: the 4-pole ungrounded quarter-wave bandpass filter and a 5-pole quarter-wave filter with each resonator grounded on alternating ends. The bandwidth of the 4-pole filter is less than the 5-pole, and the insertion loss of both filters is slightly over 4.2 dB as measured in the first test. Since the insertion loss is dependent on how accurately the filter is constructed, this figure can be improved.

Another filter design that is described by James Davey is the 5-pole quarter-wave hairpin filter. This filter has its elements folded in half with every other element reversed (see Figure 2 (c)). No ground connections are required. Coupling between elements of the hairpin filter is closer than in the parallel strip filters and needs to be adjusted through trial and error. According to Mr. Davey, test results of the hairpin filter were very good. Filter loss was 1.5 dB and the ripple was 0.2 dB.

Using the copper tape fabrication procedure, you can experiment with any of these filters, or build a power splitter or directional coupler. The filters we will build are the narrow bandwidth 4-pole design shown in Figure 2 (a) and the wider bandwidth 5-pole design shown in Figure 2 (b).

List of Givens and Knowns

Our circuit will use the standard G10 epoxy fiber printed circuit (pc) board with copper clad on one side only.

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The total thickness of the board is 1.41 mm (as measured with a micrometer). The number we will use in the microwave formulas will be the thickness of only the substrate, which is 1.37 mm.

Let's start with a list of definitions and symbols, some of which we will use in the formulas.

List of Formulas

The microwave formulas we will use are listed below. For more information on this subject, see the list of references at the end of this article.

A. W = ratio × h (Ref. 1)

B. To calculate full wavelength in

$$\text{cm}, \lambda = \frac{C_{\text{eff}}}{f}$$

Note: This is an approximation since the speed of light in free space differs from that in a dielectric. However, for these calculations, the results are very close.

C. To calculate quarter wavelength

$$\text{in cm}, \lambda = \frac{\text{cm}}{4}$$

D. Separation between microstrip resonators in mm,

$$S = h + \frac{t}{2} \text{ (Ref.3)}$$

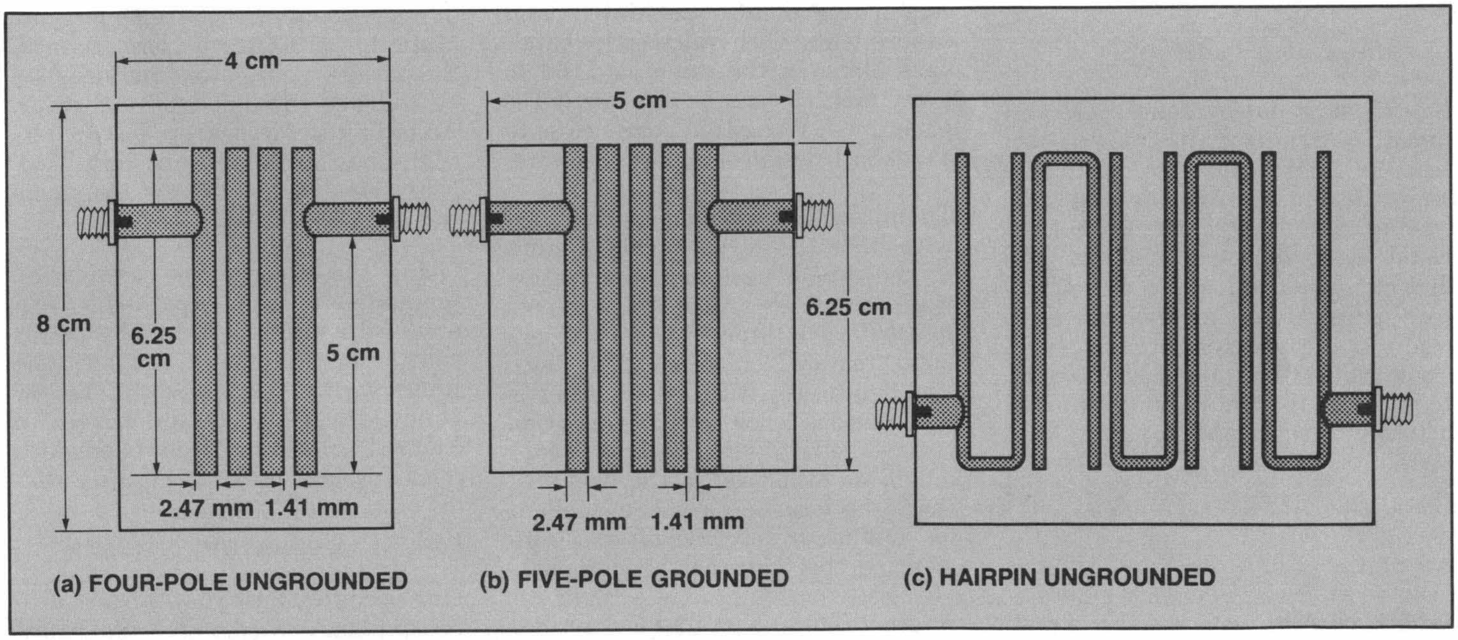
A. C = Velocity of light = 30×10^9 cm/sec
B. λ = Wavelength in cm
C. f = Bandpass center frequency of 1.2 GHz
D. h = Height (or thickness) of the substrate
E. W = Width of the microstrip (copper tape)
F. t = Thickness of copper tape
G. Z_o = Impedance (self-impedance per unit length – 50 ohms)
H. S = Separation between strip resonators
I. VSWR = Standing wave ratio
J. Ratio = Ratio of the thickness of the substrate to the width of the copper tape
L. ϵr = Relative dielectric constant of the substrate

Calculations

Working through the following formulas will determine the fundamental characteristics of a bandpass filter. The answers I am presenting here are highlighted and apply only to the example filter for this article. By changing the impedance, bandpass center frequency specifications, or the type of pc board material, you can build a filter that will meet your own specifications.

Copper Strip Width

The first step is to solve for the width of each copper strip. The width of the copper strip works with the physical characteristics of the pc board to determine the impedance of the filter. To solve that equation we need to use Figure 3 (Ref. 1) to find the ratio factor for the epoxy G10 board. (Figure 3 shows the dielectric constant for other types of boards, but epoxy G10 is the most common and is the one I have selected for our filter.) The chart shows that the dielectric constant for an epoxy board is 4.8. Since we are building a filter that is terminated to 50 ohms, follow the curve to where it intersects with the 50-ohm horizontal line, then trace straight down to the bottom line. Note that Figure 3 provides imped-



(a) FOUR-POLE UNGROUNDED
(b) FIVE-POLE GROUNDED
(c) HAIRPIN UNGROUNDED

Figure 2. Three types of bandpass filter design (not drawn to scale)

ance figures for a single-strip transmission line. Therefore, the 50-ohm impedance of an isolated strip is a rough approximation of a real case. The coupling effect of adjacent strips changes the complex impedance, which lowers the net impedance (Z_0). And the lower the net impedance, the higher the insertion loss.

For this example, the ratio is shown to be 1.8. This is the ratio of the height (thickness) of the dielectric to the width of the copper strip. Since the thickness of the dielectric is already known (see the list of givens above), we can easily solve for the copper tape width. From the list of formulas, we use formula A:

A. $W = \text{ratio} \times h$
$W = 1.8 \times 1.37$
$W = 2.47\ \text{mm}$

Copper Strip Length

The next step is to calculate the length of each copper strip, which determines the bandpass frequency. The 4-pole and 5-pole filters differ slightly in this calculation due to the effect of grounding the opposite ends of every other resonator in the 5-pole design. The grounded end of the 5-pole filter doubles the **effective** length of the strip, which means that for the same bandpass frequency, the **actual** length of the copper strip needs to be half the calculated value. From the list of formulas we use formulas B and C:

B. Full wavelength in cm

$$\lambda = \frac{C_{\text{eff}}}{f} \qquad \lambda = \frac{30 \times 10^9}{1.2 \times 10^9}$$

$\lambda = 25$ cm (12.5 cm for the 5-pole)

C. Quarter wavelength in cm

$$\lambda = \frac{\text{cm}}{4} \qquad \lambda = \frac{25}{4}$$

$\lambda = 6.25$ cm (3.125 cm for the 5-pole)

We will build the filter in quarter wavelength since it takes less space. Note that the overall frequency of the 5-pole filter is half the value of the 4-pole when using the same length copper strips.

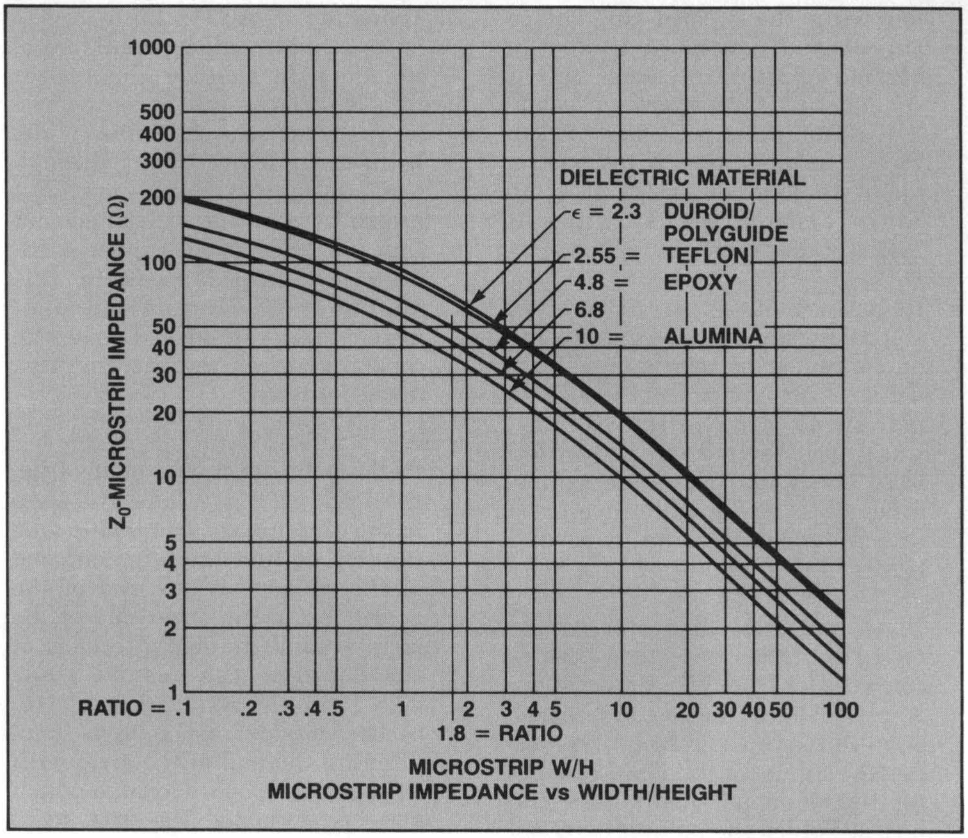


Figure 3. Chart showing ratio of substrate thickness to width of the copper tape.

Separation Between Copper Strips

The final step is to calculate the separation between the copper strips, which determines the bandwidth and passband ripple. From the list of formulas, we use formula D (Ref. 3):

D. Separation between microstrip resonators

$$S = h + \frac{t}{2} \qquad S = 1.37 + \frac{.076}{2}$$

$S = 1.41$ mm

Building Steps

Four-Pole Design

1. The first step is to cut a 5 cm × 8 cm board from the G10 stock using shop shears, then sand the edges smooth. Now scribe a guide line down the center of the dielectric side of the board (long way) so you can lay the copper strips in a straight line. It would be a good idea to clean the board with alcohol to remove any oil residue that would prevent the copper strips from sticking. Set the board aside.

2. Cut several pieces of copper tape the same length as the board.

3. Using an X-ACTO knife and a good straight edge (small metal metric ruler), score the copper tape lengthwise into at least six strips that are 2.47 mm wide, being careful not to cut through the adhesive backing tape. For proper termination, it is important that the width of the copper strips be as accurate as possible; this helps minimize VSWR ratio and insertion loss. Leave the copper strips on the backing tape until needed.

4. Score across one end of the strips. Then trim four of the strips to approximately 3 mm longer than 6.25 cm (6.25 cm + 3 mm). This 3 mm excess will be used for fine-tuning the filter during the test procedure. The 3 mm excess will also lower the center frequency by approximately 30 MHz. You can trim the strips one mm at a time, later in the test procedure.

5. Peel one of the copper strips from the backing tape. Place the first strip on the center of the board

following the scribed line. Place the second copper strip to the outside of the first strip with a spacing of 1.41 mm (from the earlier calculations with formula D). Place the next two strips on the opposite side of the first strip maintaining the spacing of 1.41 mm between each strip.

6. Refer to Figure 2 (a). Place the W2 connector strips 5 cm from one end of the strips, overlapping each outside W1 strip half way. The placement of W2 in this example was selected to minimize insertion loss. The actual placement in another filter design will have to be accomplished through trial and error.

7. Place the OSM connector on the board so that the solder post is centered on the W2 copper strip. Apply solder to the post and copper strip to make the connection. Solder the flange of the OSM connector to the copper-clad side of the board. Solder the point where W2 overlays W1.

Five-Pole Design

I am making the physical length of this filter the same length as the 4-pole filter to demonstrate that alternately grounding the ends of the strips causes the effective length of the strips to double, which lowers the overall frequency by half. Since the calculations for the length of the strips for the 4-pole filter indicated 6.25 cm, I will cut the 5-pole board this same exact length and wrap every other end of the copper strips around the end of the board and solder them to the ground plane.

1. Cut a 6 cm × 6.25 cm board from the G10 stock using shop shears, then sand the edges smooth. Now scribe a guide line down the center of the dielectric side of the board (long way) so you can lay the copper strips in a straight line. It would be a good idea to clean the board with alcohol to remove any oil residue that would prevent the copper strips from sticking. Set the board aside.

2. Cut several pieces of copper tape about 7 cm long.

3. Using an X-ACTO knife and a good straight edge (small metal metric ruler), score the copper tape lengthwise into at least seven strips that are 2.47 mm wide, being careful not to cut through the adhesive backing tape. For proper termination, it is important that the width of the copper strips be as accurate as possible; this minimizes VSWR ratio and minimizes insertion loss. Leave the copper strips on the backing tape until needed.

4. Peel one of the copper strips from the backing tape. Place the strip in the center of the board following the scribed line and align one end of the strip with one end of the board. Wrap the other end of the strip around the opposite edge of the board to the ground plane side. Place the second copper strip to the outside of the first strip, aligning the end of the strip with the end of the board around which you just wrapped the first strip. Maintain the spacing between the strips at 1.41 mm (from the earlier calculations with formula D). Place the remaining strips on the board, alternating the ends that are aligned with the end of the board, wrapping each opposite end around the edge of the board to the ground plane. See Figure 2 (b).

5. Refer to Figure 2 (b). Place the W2 connector strips 5 cm from one end of the strips, overlapping each outside W1 strip half way. The placement of W2 in this example was selected to minimize insertion loss. The actual placement in another filter design will have to be accomplished through trial and error.

6. Place the OSM connector on the board so that the solder post is centered on the W2 copper strip. Apply solder to the post and copper strip to make the connection. Solder the flange of the OSM connector to the copper-clad side of the board. Solder the point where W2 overlays W1. Solder each wrapped end of the copper strips to the ground plane.

Test Procedure

I tested both filters with a Hewlett-Packard Model 8510 Network Analyzer. This analyzer provided the frequency response and delay distortion measurements shown in Figures 4 and 5. The phase data is required to measure delay distortion or group delay. Delay distortion occurs when different frequency components of a complex waveform experience nonlinear phase shifts. Group delay is a measurement of this distortion and is measured using several techniques; the most common being phase slope (which is what I used), amplitude modulation, frequency modulation, and frequency deviation.

It is important for the reader to realize that if phase response is crucial to your filter characteristics, then you must use a microwave vector network analyzer similar to the HP 8510 (or HP 8753–Ref. 6) to characterize the filter. On the other hand, if phase response is not so crucial, and the cost plus accessability of test equipment becomes a limiting factor, refer to HP Application Note 183 (Ref. 7) for other measurement solutions.

Fine Tuning the Filter

The two filters can be tuned in several ways. If you use the X-ACTO knife and cut one mm from the ends of the strips, you will increase the center frequency. Conversely, if you add to the strips you will lower the center frequency.

If the VSWR is high, you will have high insertion loss. This could be due to the coupling effect of adjacent strips changing the complex impedance (discussed earlier in the paragraph on determining the copper strip width). Remember that the calculations from the ratio chart in Figure 3 are only approximations of a real case.

Also, if the insertion loss is high, you want to pay close attention to the precision of the copper strips. Make certain that the strips have smooth edges and are lying flat on the board. Use a burnishing tool (a ball point pen works nicely) to rub the strips

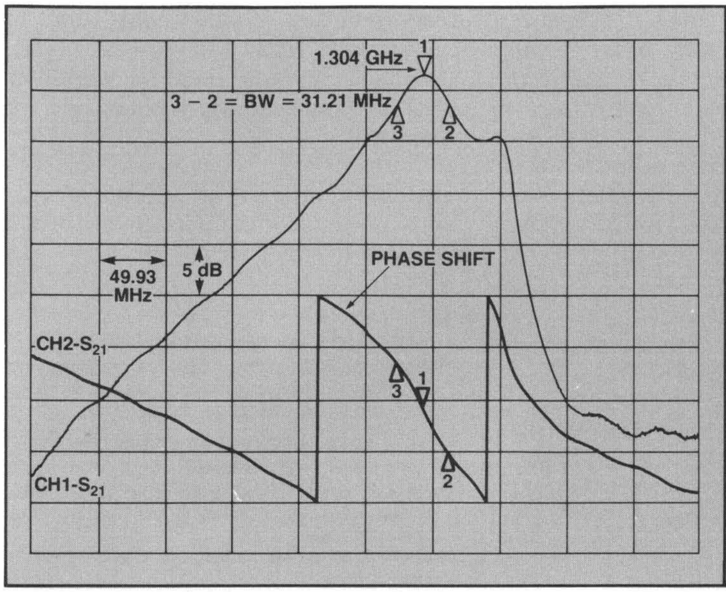


Figure 4. Four-pole filter frequency response and phase shift plot. The insertion loss is 3.4 dB.

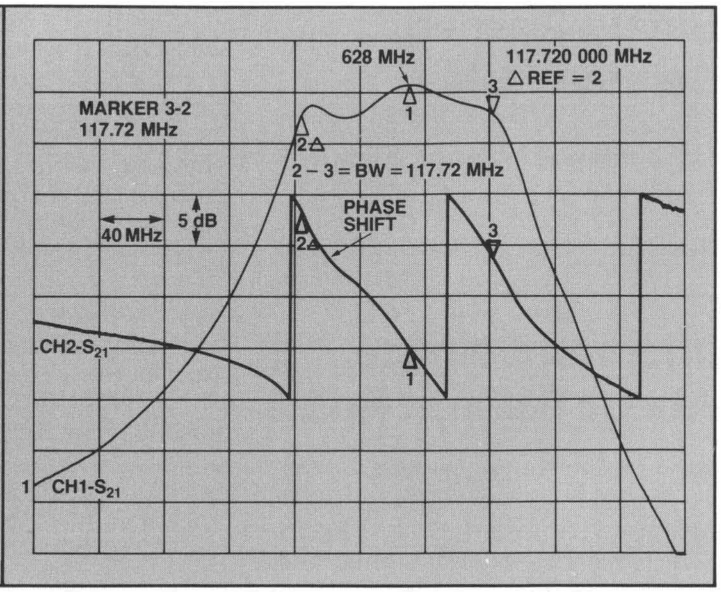


Figure 5. Five-pole filter frequency response and phase shift plot. The insertion loss is 4.2 dB.

flat. Also keep in mind that the formulas did not take into account the thickness of the adhesive of the copper strips, which can change the figures ± five percent.

Finally, the filter bandwidth and passband ripple are determined by the spacing between the resonators. Try changing the spacing between the first and last resonators. This changes the "Q" which affects the insertion loss. Overall, fine tuning can improve the insertion loss by < 2dB.

Table 1. List of Supplies

Description		HP P/N
Roll of Adhesive-Backed Copperfoil Tape 1″ Wide	3M Scotch #1181	0460-0762
Roll of Adhesive-Backed Copperfoil Tape ¾″ Wide	Permacel #P-391	—
Roll of Clear Mylar Tape With Yellow Adhesive	3M Scotch #8428	—
Roll of Clear Mylar Tape With Clear Adhesive	3M Scotch #850	—
OSC Connector	2052-1628-02	

Conclusion

The purpose of using copper tape to construct the microstrip filter is to allow you to, in a sense, "breadboard" the filter to obtain "rough results" before you etch the final printed circuit. The breadboard circuit should provide you the bandpass and bandwidth figures to within approximately 15 percent accuracy. However, for phase response, it is very important to understand that this method of design construction is very limiting due to the somewhat uncontrolled phase results.

The method of construction I have presented in this article is only an approximation. Phase delay plays an important part in filter design and must always be taken into consideration. I hope that you will experiment with this method and refine the measurements into a workable model that can be used as a blueprint for an etched pc board.

References

1. Communications Transistor Corp., *Design Charts To Aid in RF Power Amplifier Design,* Microstrip Impedance vs. Width/Height. Wheeler's equations are used.
2. Harlan Howe, Jr.: *Stripline Circuit Design,* Artech House, Inc. 1974, Dedham, MA.
3. K.C. Gupta, Ramesh Garg, I.J. Bahl: *Microstrip Lines and Slotlines,* Artech House, Inc., 1979, Dedham MA.
4. Stephen A. Maas: *Microwave Mixers,* Artech House, Inc., 1986, Dedham, MA.
5. I.J. Bahl, D.K. Trivedi: "A Designer's Guide to Microstrip Line," *Microwaves,* May 1977.
6. *HP 8753B Network Analyzer User's Guide,* HP Part No. 08753-90007.
7. HP Application Note 183, *High Frequency Swept Measurements,* HP Publication No. 5952-9200. ☐

Safety-Related Service Notes

HP 35660A Dynamic Signal Analyzer

Product Safety Service Note 35660A-01-S describes a possible safety hazard that may occur if the screw that secures the right front handle becomes loose.

The safety service note describes the procedure of applying a thread locking compound to the handle screw nearest CHANNEL 2's input. The recommended locking compound is Loctite 242, HP P/N 0470-0231. Note that the compound must be reapplied to this handle screw whenever it is removed.

You may order this safety service note using the *Bench Briefs* order form on the rear page. ☐

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Update service	5951-6517

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HP 3235A/E SWITCH/TEST UNIT

3235A/E-7. HP 34520A DMM serial numbers: 2628A00363 and below. Incorrectly inserted capacitor.

HP 3453A DIGITAL STIMULUS/RESPONSE UNIT

3453A-7A. All serials. DSRU reference board gain and offset adjustment.

HP 3562A DYNAMIC SIGNAL ANALYZER

3562A-10. Serials: Approx. 2738A02975 to 2738A03390. Modification to improve power supply reliability.

HP 3582A SPECTRUM ANALYZER

3582A-15. All serials. Specifications for correct ac main fuse.

HP 3852X CONTROLLER FOR HP 3852A

3852X-6. Serials 2710A03189 and below. Fixes, changes, and enhancements made in firmware revision 3.0.

HP 4954A PROTOCOL ANALYZER

4954A-3. Serial numbers less than 2745A00600. Recommended modification to cure a performance verification loop test 32 or 33 failure.

HP 5061A CESIUM BEAM FREQUENCY STANDARD

5061A-13A. All serials. Replacement kit for cesium oven controller (P/N 05061-6173).

HP 5180A WAVEFORM RECORDER

5180A-23. Series prefixes 2808A and below with the following exceptions: 2808A01327, 2808A01328, 2808A01331, 2808A01332, 2808A01333, 2808A01334, 2808A01335. Improve memory related problems to increase reliability.

HP 5182A WAVEFORM RECORDER AND GENERATOR

5182A-3. Series prefixes 2808A and below with the following exceptions: 2808A00533, 2808A00534, 2808A00535, 2808A00536, 2808A00537, 2808A00538, 2808A00539, 2808A00540. Improve memory related problems to increase reliability.

HP 5183A WAVEFORM RECORDER

5183A-2A. All serial prefixes. Software modification to the basic recorder driver to improve performance (software revision 2812 and below).

HP 5342A MICROWAVE FREQUENCY COUNTER

5342A-41B. Serials 2317A07386 through 2317A07905. Installing grounding screws to eliminate high frequency miscount.

5342A-49A. All serials. Modification to prevent HP-IB lock-up problem.

5342A-50. All serials. Improved IF adjustment procedures.

HP 5343A MICROWAVE FREQUENCY COUNTER

5343A-26A. All serials. Modification to prevent HP-IB lock-up problem.

5343A-28. All serials. Improved IF adjustment procedures.

HP 5355A AUTOMATIC FREQUENCY CONVERTER with the HP 5345A Electronic Counter and the HP 5356A/B/C/D Frequency Converter Heads

5355A-4. HP 5355A serial prefixes 2242A to 2732A. Modifications to eliminate error code 83, 86, 89 problem.

HP 5359A TIME SYNTHESIZER

5359A-8. Serials 2714A01371 and below. Modification to reduce dc offset drift.

HP 5371A FREQUENCY AND TIME INTERVAL ANALYZER

5371A-2A. Serial prefixes 2812A and below. Instructions for installing retrofit kit, HP P/N 05371-67002, firmware revision 2820 upgrade.

5371A-3A. Serials 2707A00101 through 2707A00160. HP 5371As with modification on A6 DMA/gate board may indicate A5 ZDT failure on power-up.

5371A-4. All serials. Instructions for installing option 060 rear panel inputs retrofit kit, P/N 05371-60230.

5371A-6. Serials 2824A and below. Instructions for installing ZDT field replacement service kit, P/N 05371-67003, for the A5 ZDT/count assembly, P/N 05371-60025.

5371A-7. All serials with firmware revisions 2742, 2748 and 2812. Firmware revision anomalies and their workarounds.

5371A-8A. All serials with firmware revision 2828 installed. Firmware revision anomalies and their workarounds.

5371A-9. Serials 2707A00101 through 2707A00160. Inoperative save/recall feature may be due to bad lithium battery.

5371A-10. Serials 2707A00101 through 2707A00112, 2707A00115, 2707A00117 through 2707A00125, 2707A00128, 2707A00129. A6 DMA/gate assembly modification to correct a possible miscount problem.

HP 6030A DC POWER SUPPLY

6030A-08. Serials 2811A00815 and above. Relay link enhancement for standard models. (A8 HP-IB interface assembly part numbers 06031-61006 and 06031-61007).

HP 6031A DC POWER SUPPLY

6031A-10. Serials 2817A-00983 and above. Relay link enhancement for standard models (A8 HP-IB interface assembly part numbers 06031-61006 and 06031-61007).

HP 6032A DC POWER SUPPLY

6032A-09. Serials 2818A-03121 and above. Relay link enhancement for standard models (A8 HP-IB interface assembly part numbers 06031-61006 and 06031-610007).

HP 6033A DC POWER SUPPLY

6033A-07. Serials 2817A-03452 and above. Relay link enhancement for standard models. (A8 HP-IB interface assembly part numbers 06031-61006 and 06031-61007).

HP 6038A DC POWER SUPPLY

6038A/L-05. Serials 2817A-05426 and above. Relay link enhancement for standard models (A8 HP-IB interface assembly part numbers 06031-61006 and 06031-61007).

HP 6621A/6622A/6623A/6624A DC POWER SUPPLIES

6621A-01, 6622A-01, 6623A-01, 6624A-01.
6621A. Serials 2611A00110 and below;
6622A. Serials 2611A00160 and below;
6623A. Serials 2611A00120 and below;
6624A. Serials 2624A00310 and below.
Modification to allow the Series 300 computer to boot with power supply on (part required is ROM 5080-2093).

6621A-02, 6622A-02, 6623A-02, 6624A-02.
6621A. Serials 2711A00340 and below;
6622A. Serials 2701A00520 and below;
6623A. Serials 2652A00400 and below;
6624A. Serials 2652A01070 and below.
Microprocessor change to improve performance.

6621A-03, 6623A-03.
6621A. Serials 2636A00240 and below;
6623A. Serials 2635A00260 and below.
Modifications to prevent power transformer from overheating at maximum output.

6621A-04, 6623A-04.
6621A. Serials 2644A00280 and below;
6623A. Serials 2640A00300 and below.
Power transformer change to increase available output voltage.

6621A-05, 6622A-03, 6623A-05, 6624A-03.
6621A. Serials 2644A00280 and below;
6622A. Serials 2627A00460 and below;
6623A. Serials 2649A00340 and below;
6624A. Serials 2631A00890 and below.
Insulator added to power transformer.

6621A-06, 6622A-04, 6623A-06, 6624A-04.
6621A. Serials 2742A00411 and below;
6622A. Serials 2740A00621 and below;
6623A. Serials 2740A00471 and below;
6624A. Serials 2740A01291 and below.
Power hybrid U338 and U339 design change to prevent oscillation.

6623A-07. Serials 2751A00631 to 2751A00665. PC board track may short transformer.

6624A-05. Serials 2750A01621 to 2804A01773. PC board track may short transformer.

HP 6942A/43A MULTIPROGRAMMERS HP 14700A AND 14701A Transmission Boards

6942A-16/6943A-7. Serials 2740A01055 and below, and serials 2749A00370 and below. Modification to prevent self-test errors.

HP 6954A MULTIPROGRAMMER

6954A-02. All serials. Programatically changing video refresh rate when using 50 Hz power to improve performance of the HP 37531A Video Monitor.

HP 8559A SPECTRUM ANALYZER

8559A-31. Serial prefix 2819A and below. Sweep generator board with improved +10 volt reference power supply.

HP 8614A/8616A SIGNAL GENERATOR

8614A-20/8616A-18. All serials. CR701 detector replacement kit.

HP 8642A/B SYNTHESIZED SIGNAL GENERATOR

8642A-8, 8642B-8. A11 and A12 module serial prefixes 2737A and below. Procedure to resolve A11 and A12 trimcap leakage.

HP 8662A SYNTHESIZED SIGNAL GENERATOR

8662A-16. All serials. Power supply module (A7) is available as an exchange assembly part number 08662-69001.

HP 8663A SYNTHESIZED SIGNAL GENERATOR

8663A-10. All serials. Power supply module (A7) is available as an exchange assembly part number 08662-69001.

HP 8671B SYNTHESIZED SIGNAL GENERATOR

8671B-03A. All serials. Preferred replacement for precision resistors.

HP 8671B SYNTHESIZED SIGNAL GENERATOR

8671B-04. Serial prefixes 2752A and below. Preferred replacement for the A3A5 DAC assembly.

8671B-05. Serial prefixes 2708A through 2823A. Improved reliability of the 20-30 MHz phase detector.

HP 8672A SYNTHESIZED SIGNAL GENERATOR

8672A-20A. All serials. Preferred replacement for precision resistors.

8672A-21. Serial prefixes 2747A and below. Preferred replacement for the A3A5 assembly.

8672A-22. Serial prefixes 2708A through 2823A. Improved reliability of the 20-30 MHz phase detector.

HP 8673B SYNTHESIZED SIGNAL GENERATOR

8673B-6A. Serial prefixes 2634A to 2704A. Preferred replacement for A2A10 and A2A11 assemblies.

8673B-14A. All serials. Preferred replacement for precision resistors.

8673B-15. Serials 2747A01081 to 2747A01126. Modification for improved reliability of the + 5V supply.

8673B-16. Serial prefixes 2747A and below. Preferred replacement for the A3A5 DAC assembly.

8673B-17. Serial prefixes 2708A through 2823A. Improved reliability of the 20-30 MHz phase detector.

HP 8673C SYNTHESIZED SIGNAL GENERATOR

8673C-6A. Serial prefixes 2634A to 2704A. Preferred replacement for A2A10 and A2A11 assemblies.

8673C-15A. All serials. Preferred replacement for precision resistors.

8673C-17A. Serials 2747A00474 to 2747A00503. Modification for improved reliability of the + 5V supply.

8673C-18. Serial prefixes 2747A and below. Preferred replacement for the A3A5 DAC assembly.

8673C-19. Serial prefixes 2708A through 2822A. Improved reliability of the 20-30 MHz phase detector.

HP 8673D SYNTHESIZED SIGNAL GENERATOR

8673D-6A. Serial prefixes 2634A to 2704A. Preferred replacement for A2A10 and A2A11 assemblies.

8673D-16A. All serials. Preferred replacement for precision resistors.

8673D-18. Serials 2747A00593 to 2747A00673. Modification for improved reliability of the + 5V supply.

8673D-19. Serial prefixes 2747A and below. Preferred replacement for the A3A5 DAC assembly.

8673D-20. Serial prefixes 2708A through 2822A. Improved reliability of the 20-30 MHz phase detector.

HP 8673E SYNTHESIZED SIGNAL GENERATOR

8673E-08A. All serials. Preferred replacement for precision resistors.

8673E-09. Serials 2747A00360 to 2747A00392. Modification for improved reliability of the + 5V supply.

8673E-10. Serial prefixes 2747A and below. Preferred replacement for the A3A5 DAC assembly.

8673E-11. Serial prefixes 2708A through 2821A. Improved reliability of the 20-30 MHz phase detector.

HP 8770A ARBITRARY WAVE SYNTHESIZER

8770A-16. Serials 2812A00516 through 2812A00543. Modification to improve synchronization with other HP 8770As.

HP 8904A MULTIFUNCTION SYNTHESIZER

8904A-2. Serial prefix 2747A and below. Output overvoltage protection improvement.

8904A-3. Serial prefix 2817A and below. Modification to eliminate potential power supply short.

HP 11729C CARRIER NOISE TEST SET

11729C-3. Serial prefix 2806A and below. Modification to prevent IF amplifier instability.

HP 11848A PHASE NOISE INTERFACE

11848A-1. Serial prefix 2720A and below. Modification to eliminate potential line short.

HP 35651A HP-IB/SIGNAL PROCESSOR MODULE

3565S-5. Serial prefix 2609A and below. HP-IB/signal processor module enhancements to improve performance.

HP 35652A INPUT MODULE

3565S-4. Serial prefix 2717A and below. Input module enhancements to improve performance.

HP 35660A DYNAMIC SIGNAL ANALYZER

35660A-1-S. Serials 2816A00199 and below. The right front handle screw may come loose causing a mechanical hazard.

HP 51089A DISPLAY UNIT

51089A-6. Serials 2814A0471 and below. New A11 triple regulator board and bracket to make all units compatible with the HP 5371A.

HP 54111D DIGITIZING OSCILLOSCOPE

Serials 2733A and below. Loop 41 through 44 may fail erroneously.

HP 64120A INSTRUMENTATION CARDCAGE

64120A-1. All serials. Card slots 8 and 9 are not interrupt disabled during powerup P.V.

64120A-2. All serials. Metal filings in cardcage cause unusual and intermittent errors.

HP 64203A 8085 EMULATOR SUBSYSTEM

64203A-9. All serials. Use of control board in slots 8 or 9 of 6412A cardcage may cause failure of powerup P.V.

HP 64215A 6809 EMULATOR SUBSYSTEM

64215A-3. All serials. Use of control board in slots 8 or 9 of 6412A cardcage may cause failure of powerup P.V.

HP 64216A 6809E EMULATOR SUBSYSTEM

64216A-2. All serials. Use of control board in slots 8 or 9 of 64120A cardcage may cause failure of powerup P.V.

HP 64941A FLOPPY DISC SYSTEM

64941A-2B. All serials. Replacement instructions and exchange part numbers.

64941A-3A. Serial prefix 2560A and above. Half-height replacement instructions.

64941A-4. Serial prefix 2450A and below. Floppy disc drive replacement option.

HP 69709A POWER SUPPLY CONTROLLER CARD

69709A-2. Serials 2812A00720 and below. Modification to prevent unexpected crowbar trip.

HP 69730A RELAY OUTPUT CARD

69730A-01. All serials. Modification to HP-85A service program.

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.

Hewlett-Packard
1820 Embarcadero Road
Palo Alto, California 94303

For European customers (ONLY)

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Nederland BV
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The Netherlands

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Firm ______________________________

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- ☐ **3562A-10**
- ☐ **3565S-04**
- ☐ **3565S-05**

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- ☐ **5061A-13A**
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- ☐ **5342A-49A**
- ☐ **5342A-50**

- ☐ **5343A-26A**
- ☐ **5343A-28**
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- ☐ **5359A-08**
- ☐ **5371A-02A**

- ☐ **5371A-03A**
- ☐ **5371A-04**
- ☐ **5371A-06**
- ☐ **5371A-07**
- ☐ **5371A-08A**

- ☐ **5371A-09**
- ☐ **5371A-10**
- ☐ **6030A-08**
- ☐ **6031A-10**
- ☐ **6032A-09**

- ☐ **6033A-07**
- ☐ **6038A/L-05**
- ☐ **6621A-01,6622A-01, 6623A-01,6624A-01**
- ☐ **6621A-02,6622A-02, 6623A-02,6624A-02**

- ☐ **6621A-03,6623A-03**
- ☐ **6621A-04,6623A-04**
- ☐ **6621A-05,6622A-03, 6623A-05,6624A-03**

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- ☐ **8559A-31**
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- ☐ **8642A/B-08**
- ☐ **8662A-16**

- ☐ **8663A-10**
- ☐ **8671B-03A**
- ☐ **8671B-04**
- ☐ **8671B-05**
- ☐ **8672A-20A**
- ☐ **8672A-21**

- ☐ **8672A-22**
- ☐ **8673B-06A**
- ☐ **8673B-14A**
- ☐ **8673B-15**
- ☐ **8673B-16**

- ☐ **8673B-17**
- ☐ **8673C-06A**
- ☐ **8673C-15A**
- ☐ **8673C-17**
- ☐ **8673C-18**

- ☐ **8673C-19**
- ☐ **8673D-06A**
- ☐ **8673D-16A**
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