TIPS FOR RELIABLE WIREWRAPPING

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ABSTRACT

The unwary technician frequently constructs his first wirewrapped circuit with little or no instruction, while the wary will first seek a source of information. The unwary engineer frequently changes wires on wirewrapped circuits with little or no instruction, while the wary will first seek a source of information. The unfortunate facts show that in both cases the latter is a rare breed.

By following a few rules, and understanding why a wrapped wire makes a good connection, a reliable circuit can be produced with little effort. This paper should serve as a road map to both guide the beginner, and improve the style of the more experienced wirewrapper.

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1. Introduction

When used properly, wire wrapping has been shown to be the most reliable connection method[1] currently available. It makes connections quickly and efficiently, that may be easily changed with a few tools.

However, the wire-wrapper must be well enough informed to choose the correct wire, tool, and pins to make the connections with, and know how to evaluate the quality of the completed connection. These topics will be dealt with first, in the section on "The Wrap".

Once the wire-wrapper is capable of making a correct connection, there are other tips that help make for better circuits. The factors that affect the performance of the connection in the electrical circuit, and the ease of changing the circuit will be dealt with in the remaining sections.

2. The Wrap

The connection is made by wrapping a solid wire tightly around the corners of a connecting post while applying tension to the wire. This process both cuts a notch in the wire and deforms the post at each corner. At each corner a cold weld is thus created, causing cross migration of the metal atoms of the post and the wire[2]. While the weld does not contribute to the mechanical integrity of the connection, it does contribute to its electrical stability. The contact area is only reliable at the corners, and so the electrical properties of the connection are determined by the number of corners of the wrap.

The tension applied to the wire causes it to stretch elastically as it is wrapped. This leaves the completed connection with elastic energy stored in the lengths of wire between corners. Thus the mechanical properties of the connection are determined by the type of wire and under what tension it is wrapped. The wrap may then be considered as a collection of cold welds (at the corners), all held together by individually stretched springs (the wire betweencorners).

2.1. The Post

The connecting post length determines the number of wrapped connections that may be made to it, while its cross-section determines both the mechanical and electrical integrity of the wrap. The cross-section should be either rectangular or a parallelogram, with radii at the corners not exceeding 0.003 in. The corners, being the basis of the connection, must then be square or `sharp' to achieve a good connection. The effective sharpness of the corners should be related to the diameter of the wire, and so one should be wary of wiring too small a post with a particular wire gauge. For 30 gauge wire, the post diagonal should not exceed 0.036 inches.

The posts are usually coated with a metal such as tin or gold. This coating plays a key role, in forming the connection at the corners, by extruding away from the cold weld area into the surrounding connection. The coating thus increases the effective contact area of the corner.

2.2. The Wire

The wire provides the `spring' in the connection, and so should have good elastic properties. It should also have good electrical properties, and bond well with the post for a solid cold weld.

The wire must be solid, and may be metal coated for the same reasons that apply to the posts. Don't wrap with just any wire that fits into the bit! Typically, annealed copper wire is used, but copper alloy wires may also be used, needing fewer wraps for acceptable connection quality.

The insulation should be tough enough to prevent its being cut by the sharp corners of the posts. Unfortunately the tougher the insulation, the greater the tendency for the wire to `curl' (Curl is a wire's memory of its former shape on the spool). This makes us prefer obtaining wire on large-core spools, and choosing Kynar insulation, instead of than laminated mylar tape Teflon insulation. The Kynar is a compromise between the toughness of mylar (with its excessive curl) and the softness of Teflon (with its low capacitance and excellent thermal properties).

The wire must be correctly stripped to provide for seven wraps on the post (for 30 AWG). A slight nick in the wire at the stripping point would cause the connection to fail either during the strain of wrapping, or from future vibration, so a non-nicking wire stripper is a necessity. A separate stripping tool must be obtained for each wire gauge, as each one is precision machined for a specific wire diameter. Use of the wrong tool will cause unreliable connections.

2.3. The Bit

The bit rotates in a sleeve and wraps the wire onto the post. It is mated with the wire-wrapping tool that turns the bit at between 3000 and 5000 rpm. The correct bit-sleeve combination must be chosen for the job to be done. This is frequently where wire-wrapping fails. The wire wrapper uses the wrong bit for the posts and wires to be wrapped.

Read the instructions for choosing the bit for your post size, and wire gauge. A bit that provides a `modified wrap' should be used. It wraps one extra wrap of the insulated part of the wire around the post to keep the corners of the connection from unwelding. For specifying this type of bit, the insulation thickness must also be known.

The bit has a lifetime limited to somewhere between 50,000 and 250,000 wraps, depending on use. There may be no visible signs of the wear, so a strip-off test should be used periodically[3]. The force necessary to slide (with the correct tool) the wrapped connection off the post should exceed 3 pounds for 30 gauge wire.

Because the drive train in a wire-wrap gun expands slightly under power, the collet nut (that holds the bit in place) should be tightened by hand with the motor running. This will give longer tool life, and maximum wrapping speed.

2.4. The Connection

After sliding a piece of stripped wire into the off-center hole in the bit, the center hole of the bit is placed over the post. Applying the weight of the tool only, to the connection, the wrap should be applied, letting the tool do the work. Bad wraps are frequently made by pushing, pulling or twisting the tool.

3. Making A Net

A net[4] should be wired by connecting one post to another with as little slack as possible in the connecting wires. A common mistake in connecting a net is to create a daisy chain.

If a net contains posts 1 through 4, then a daisy chain is made by connecting post 1 to post 2, post 2 to post 3, then post 3 to post 4. If a future change requires post 1 to be removed from the net, all wires in the daisy chain must be removed (see section 5). However, by using level wrapping, this can be avoided.

The term level wrapping means that all wires will be level with the surface of the card, or both wraps of a wire will be applied to the same level of the posts. So in the above daisy chain, the wire from post 1 to post 2 is level because both wraps are on the bottom of the post. The wire from post 2 to post 3 is not level because the wrap on post 3 is on the bottom level, while the wrap on post 2 is on the second level. A level wrap for the above net would be to connect posts 1 to 2, and posts 3 to 4 on the bottom level, and then posts 2 to 3 on the second level. The wiring change here would only require removal of two wires.

The desirable feature of level wrapping is that any wiring change requires removal of at most three wires.

4. Unwrapping

When removal of connections is necessary, they should be unwrapped with an unwrapping tool. The tools for unwrapping have a hole in their center for the post, and a spiral track around the outside for the wire to slide in as it unwraps. At the tip of the spiral, there is a sharp blade that lifts the tail of the wire off the wrap. Once again, let the tool do the work, do not bear down with the unwrapping tool as the blade will be damaged.

5. Changing A Wire

Making wiring changes is simply a matter of completely removing the old wire, and replacing it with the rewire. If any other wraps are affected, the involved wire should be completely replaced. The end of a wire from an unwrapped connection should never be straightened out and rewrapped. It may seem easier at the time to cut a wire, or rewrap an already used piece of wire, but the difficulty of finding the errors induced surely outweighs the short term benefits of these practices. The practice of cutting a wire close to the post can lead to almost invisible and sometimes intermittent problems.

The wrapping process causes irreversible damage to the corners of the posts, and every rewrapping on a post furthers this damage. The only sure test of damage to a post is the strip-off test. Replacement of posts is a good feature to look for in choosing the wirewrap card.

6. The Electrical Characteristics

The electrical characteristics of wire-wrapped connections can be controlled to some extent by the layout of the wires, but more control still can be obtained by the proper choice of the wire, and card. The layout for high-speed logic (Schottky-TTL and ECL) is much more stringent than that for low-speed logic, so they will be dealt with separately.

6.1. Low Speed Logic

Low speed logic can be troublesome where a many wires all change state at the same time. The effect is serious where the wires are grouped closely together in a bundle, as the radiated fields can be large and induce spurious signals in neighboring wires. To alleviate this, the layout should avoid parallel runs of wires, and bundles of any kind. Wires are sometimes randomized during the making of a wirelist to avoid parallel runs.

The wire-wrap card may have enough ground plane to support the bandwidth of a single low-speed logic signal changing in the local area but not enough to support many of these signals changing at the same time. This problem is frequently seen when a large synchronous counter is changing from all ones to all zeros. The solution here is to spread out the ground plane loading over a larger area by distributing the counter chips around the card.

Use of more ground plane than you think you need will save you from many of the noise related debug headaches with low speed logic.

6.2. High Speed Logic

For Schottky-TTL, or ECL logic, special precautions should be taken in both the selection of the cards, the wires, and the layout. The wire insulation used may be Kynar, but Miline and Teflon insulation may be used to reduce the distributed capacitance by half.

Give serious consideration to cards that are labeled as Schottky or ECL wire-wrap cards as some of these have met with great success even with ECL-100,000 series logic. These cards may have dedicated power and ground pins that will give greatly reduced supply and ground impedance at the cost of somewhat restricted layout. When choosing cards, remember that wirewrapping to your bypass capacitors is not effective. Be wary of the manufacturers claims. Get the name of satisfied customers who are building similar technology circuits and talk to them!

The layout for high-speed logic should group functional blocks of logic together to minimize wire lengths. The wires should be randomized by either straight point-to-point wiring, or using a programmed routing of wires.

To obtain uniform impedance along the wires, use Z level wiring[5] and specify two level wire-wrap pins on the cards. The reduction in post length will reduce the impedance discontinuity caused by transmission line stub effects.

For the typical wirewrap card, wire length should be limited to 6 inches for an unterminated signal[6]. This will keep signal reflections to less than 12% undershoot, that is safely within the range of the input clamp diodes of TTL logic.

7. Debugging wire-wrap

Finding problems with wire-wrapped cards can be agonizing. By following good construction practices, these will be reduced, but the following list should help in finding the more elusive problems.

1. Two posts are touching together. Do not touch the pins in handling.

2. Small curls of wire debris are caught in the rats nest of wire, causing a short. When removing wires, shavings or curls of wire might break off the wire being removed. With the board standing on end, rap the board edge on a solid surface to shake out loose wire (don't get carried away here). Do not lay a board with pins down on an unclean surface, the board will act like a magnet and collect nuts, bolts, and loose wires!

3. A nick in the insulation has shorted. Be careful with soldering irons on wire-wrapped cards.

4. The insulation has separated on a wire and shorted. Do not overstrip and push back the extra insulation after it has been cut. Use pre-stripped wire when possible.

5. There is a pigtail shorting to an adjacent post. Do not remove the wrapping tool prematurely, let it finish the wrap.

6. A wire has been stripped back too far and is shorting to an adjacent post. Insert the wire completely into the bit. Strip correctly and choose long enough pieces of prestripped wire.

7. The printed circuit power or ground plane is shorting to a pin. Check the card before wiring for solder flecks and hair line shorts in the printed circuit. Broken traces and missing solder should also be looked for at that time.

8. A wire has fatigued and is making intermittent contact to the post. Use the right bit and wire-post combinations.

9. The sharp corner of a post has cut through the insulation of a wire. Leave a little slack where a wire makes a bend around a post. Use wire with a tough insulation.

1. Belter, Robert E., "Make ECL wire-wrapped panels re liable with proper routing and tough insulation", Electronic Design, June 7, 1979, p. 106
2. Davies, D.G., "Micro-Mechanisms of Solderless Wrapped Joint Formation", The Plessey Company Limited
3. Various tests for measuring quality of wirewraps are described in MIL-STD-1130 and EIA-STD-RS280.
4. The electrical node created by wiring posts together is called a network or `net'.
5. Z level wiring specifies that a wire must have both ends wrapped at the same level on the posts.
6. Malek and Schwartz, "IC Packaging Panels for High-speed Logic Applications", Electronic Packaging and Production, April, 1976