K4HJU

Amateur Radio
Woodcreek, Texas

Prototyping and Proof of Concept Models Part 1

Rev 0.02
Jim Satterwhite K4HJU

A Work in Progress

K4HJU
2/25/2018

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1. Introduction

I am a little reluctant and embarrassed to present this material due to the fact that to my knowledge a major part of the system is no longer available. This process has served me so well that I would like to present it and maybe some can either find some old stock to share with the community or inspire someone to produce a likeness of the unavailable product. I will discuss this in more detail below. Fortunately for me, I have sufficient stock to last for the rest of me.

This presentation will be made in two parts. The first part will provide the evolution and the second part will present the details of the current system.

Through out my lengthy career I have been chiefly involved with designing and building prototypes and proof of concept models. A good number of engineers seem to prefer to go directly to PC Boards (PCBs) with their designs. I find that this does not work well for me. Doing it this way there are too many opportunities lost. I find that a design will evolve through the process of building and working through the process in a way that a better end result is achieved.

Through the years I have a developed a process that really works for me and I would like to share my techniques. The problem with a first out system design on a PCB is that there is inadequate flexibility especially with surface mount components. I prefer that my prototypes remain fluid right up to the finish and then commit to a PCB. I have been fortunate in my career in that most of the time I was doing product research and proof of concept modeling for new products and technologies. Most of these designs were of a kind where a similar model had not been made before. I would build the working prototype and then turn the working design over to my client to polish and package. A few times I have gone full cycle with a product. As a result I have developed some techniques that really work for me and I would like to share them with you. I know of no one using these techniques other than myself.

A lot of the time the terms breadboard and prototype are used interchangeably. Most hams are aware where the term breadboard comes; however some of the new folks may not know it's origin. In the "old" days prototypes were built up upon wooden boards. Boards from the kitchen that bread was made on; thus "bread" "board". I still have some Bell Labs breadboards in my lab. Today prototypes and components have changed considerably and different techniques are required, yet the name sticks.

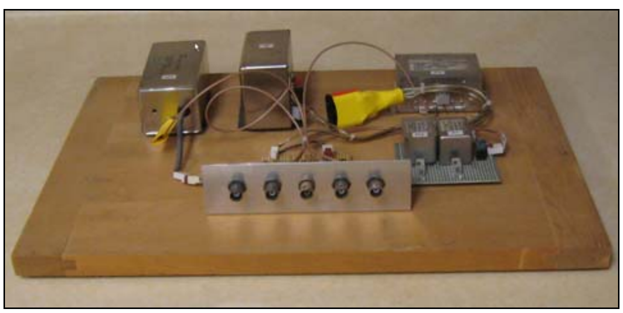


Figure 1-1 Breadboard

I have built systems employing vacuum tubes on aluminum chassis's. Today I am using modules made with surface mount components lashed together using insulation displacement connection (IDC) wiring to build complex flexible systems. There has been quite an evolution in the process. Here is an example of what I have evolved to and then I will go to the evolution of my technique.

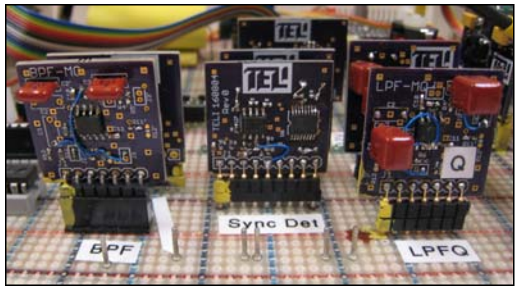


Figure 1-2 Small Functional Modules

At present I am using functional modules that I design and have PCBs made that employ surface mount components to achieve a relatively high density. It turns out that this is an economical approach, as the cost of the PCBs is $5 per square inch for three boards with no setup fee. Therefore, if something needs a little tweaking or an error needs to be corrected, it is economic to do so. The modules once designed are available for other systems in the future.

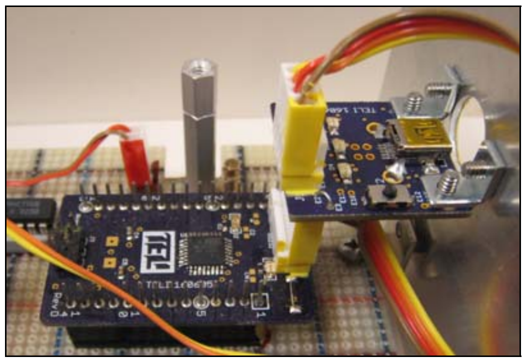


Figure 1-3 Microprocessor and USB-RS232 Modules

One of the modules I designed early on was my version of the early Arduino microcomputer board. The Arduino board did not suit me for a number of reasons. I wanted more pins and I wanted to separate the USB-RS232 function from the microcontroller board. I found that, particularly in those days the USB cable would "man-handle" the board the Arduino was mounted on and I wanted to avoid that by mounting the USB-RS232 module to the panel. Figure 1-3 shows one example of the microcontroller board and the separate USB-RS232 module. I have used this configuration on many of the systems I have designed.

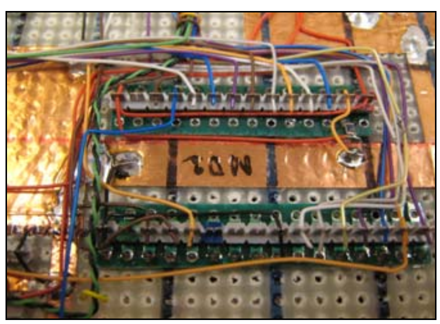


Figure 1-4 Insulation Displacement Connection (IDC) Wiring

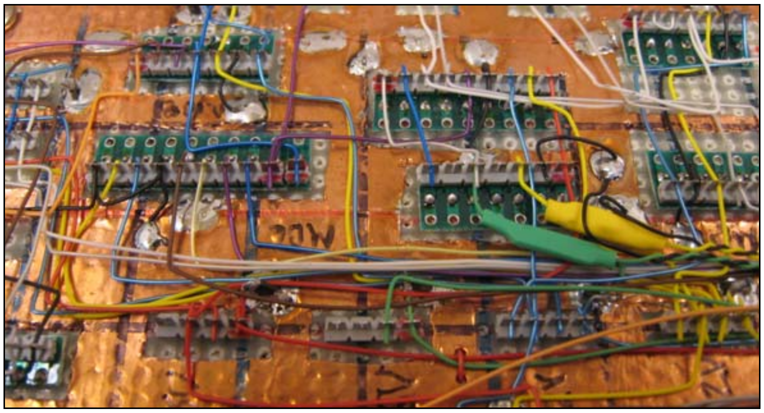


Figure 1-5 IDC Wiring

The connections are made using 3M IDC strips and 30 ga. wire-wrap wire. This allows an easily changeable, traceable and documentable configuration. If you are interested in how I got there, read on, else jump to Part 2.

2. Evolution

I will concentrate here mainly on systems built around solid state devices. In the early days there were a number of methods used. One constant through all this time has been the perforated PCB. There have been a number of varieties and I prefer .062" FR4 material punched on 100 mil centers. This material can be cut to the shape needed rather easily.

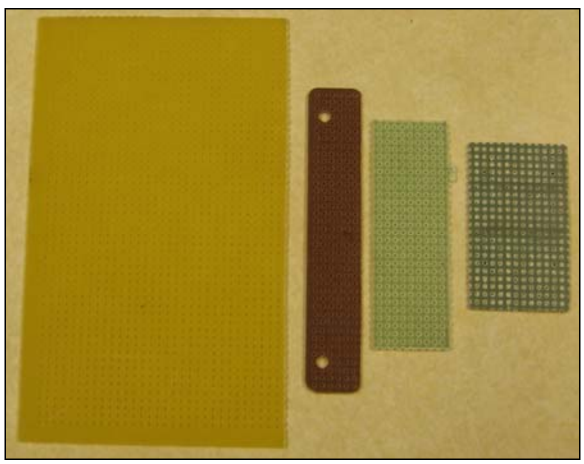


Figure 2-1 Examples of .062" 100 mil Perforated PCB Material

Going back to the beginning, the first configurations employed .062" 200 mil perforated boards, sockets for transistors and "fleas". Fleas were a solder connection for components that were pressed through the PCB board. It was a bit messy; however it worked. I no longer have any examples of this construction.

From that evolved the move to 100 mil boards and contacts designed for those boards; however it was much the same.

For these systems it was point to point solder wiring.

With the advent of digital ICs came several interconnection systems. An early, circa 1969, system that I tried was as shown in Figure 2-2 is an Augat interconnection system. While convenient to implement, it was a nightmare if something was disturbed. I was quickly in search for something better.

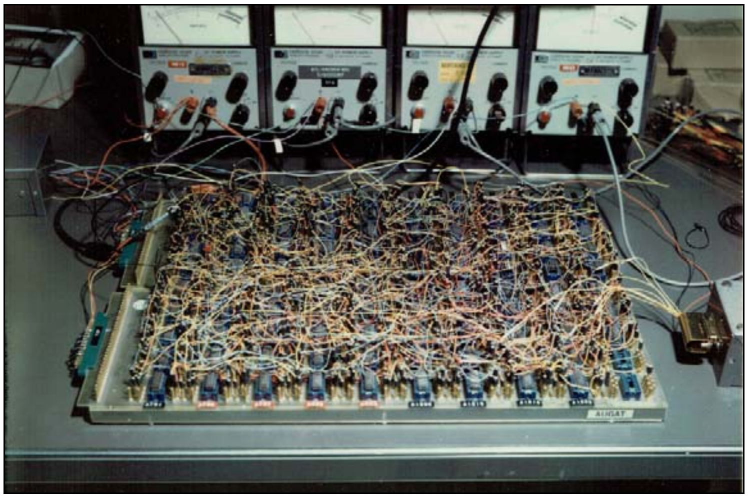


Figure 2-2 Augat Interconnection System

The next method was wire-wrap. With wire-wrap the density could be increased significantly and documentation became easier, although handling components such as resistors, capacitors and connectors was still problematic. The documentation issue comes from being able to make changes and have the drawings and hardware match. Remember at this time drawings were pencil and paper. Changes could be made by unwrapping a wire and either replacing it or moving it elsewhere. What happens if the desired wire is the lower wrap on a multi-wrap post? Then you have several connections to get put back right. Also, when you unwrapped a wire, is there enough length to make a new connection? So, wire-wrap is better; however it had it's own share of problems. As an aside, there were large product boards made by Western Electric and maybe others using programmed wire-wrap machines.

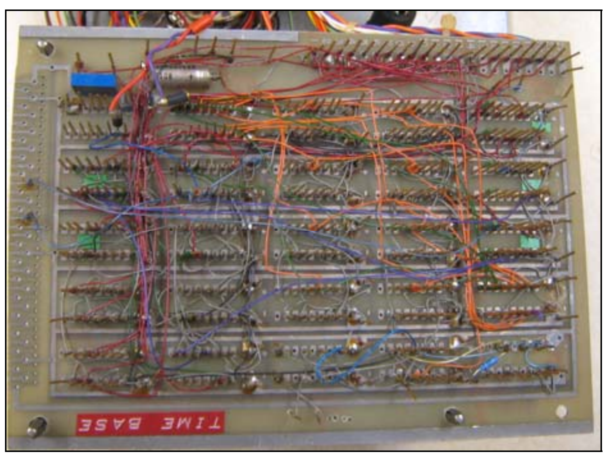


Figure 2-3 Wire-Wrap Wiring Connection Side

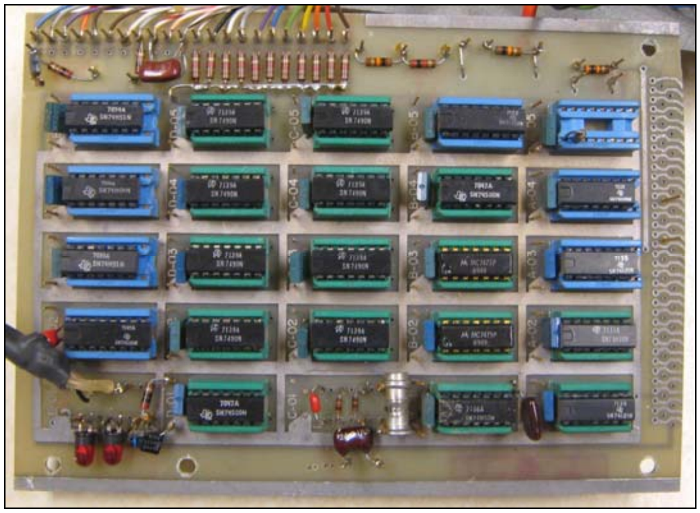


Figure 2-4 Wire-Wrap Wiring Component Side

Wire-wrap worked pretty well for digital systems; however for analog systems it was more difficult. There were component wire-wrap pins using a solder wire-wrap pin that pressed into the board.

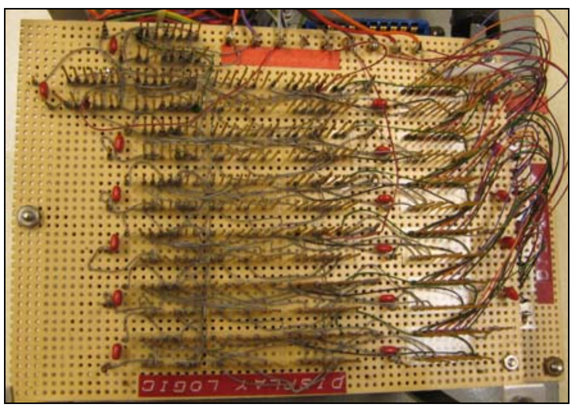
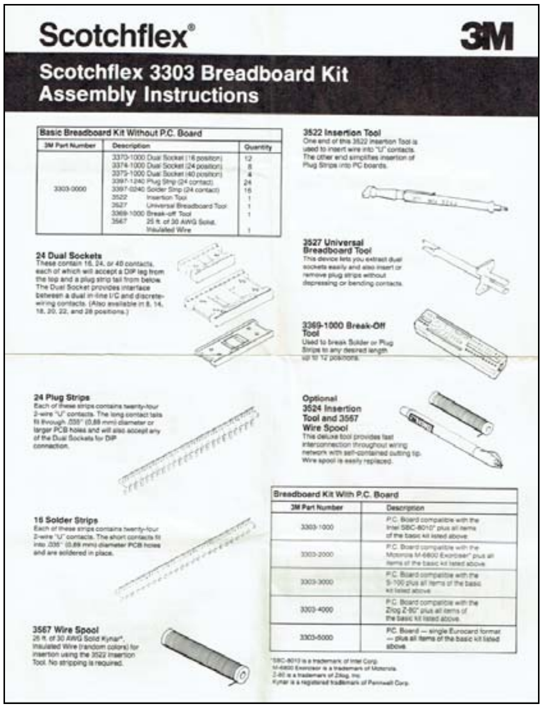


Figure 2-5 Wire-Wrap Wiring Connection Side - Another Example

The big break for me came around 1980 when a fellow engineer, Armond Cosman, gave me a 3M IDC bread boarding system kit. I started using it and was really impressed.



Scotchflex® 3M

Scotchflex 3303 Breadboard Kit Assembly Instructions

Basic Breadboard Kit Without P.C. Board		
3M Part Number	Description	Quantity
3303-0000	3370-1000 Dual Socket (16 position)	12
	3374-1000 Dual Socket (24 position)	8
	3379-1000 Dual Socket (40 position)	4
	3397-1240 Plug Strip (24 contact)	24
	3397-0240 Solder Strip (24 contact)	16
	3522 Insertion Tool	1
	3527 Universal Breadboard Tool	1
	3369-1000 Break-off Tool	1
	3567 25 ft. of 30 AWG Solid, Insulated Wire	1

24 Dual Sockets
These contain 16, 24, or 40 contacts, each of which will accept a DIP leg from the top and a plug strip tail from below. The Dual Socket provides interface between a dual in-line I/C and discrete-wiring contacts. (Also available in 8, 14, 18, 20, 22, and 28 positions.)

24 Plug Strips
Each of these strips contains twenty-four 2-wire "U" contacts. The long contact tails fit through .035" (0.89 mm) diameter or larger PCB holes and will also accept any of the Dual Sockets for DIP connection.

16 Solder Strips
Each of these strips contains twenty-four 2-wire "U" contacts. The short contacts fit into .035" (0.89 mm) diameter PCB holes and are soldered in place.

3567 Wire Spool
25 ft. of 30 AWG Solid Kynar*, Insulated Wire (random colors) for insertion using the 3522 Insertion Tool. No stripping is required.

3522 Insertion Tool
One end of this 3522 insertion Tool is used to insert wire into "U" contacts. The other end simplifies insertion of Plug Strips into PC boards.

3527 Universal Breadboard Tool
This device lets you extract dual sockets easily and also insert or remove plug strips without depressing or bending contacts.

3369-1000 Break-Off Tool
Used to break Solder or Plug Strips to any desired length up to 12 positions.

Optional 3524 Insertion Tool and 3567 Wire Spool
This deluxe tool provides fast interconnection throughout wiring network with self-contained cutting tip. Wire spool is easily replaced.

Breadboard Kit With P.C. Board	
3M Part Number	Description
3303-1000	P.C. Board compatible with the Intel SBC-8010* plus all items of the basic kit listed above
3303-2000	P.C. Board compatible with the Motorola M-6800 Exorciser* plus all items of the basic kit listed above
3303-3000	P.C. Board compatible with the S-100 plus all items of the basic kit listed above
3303-4000	P.C. Board compatible with the Zilog Z-80* plus all items of the basic kit listed above
3303-5000	P.C. Board — single Eurocard format — plus all items of the basic kit listed above

*SBC-8010 is a trademark of Intel Corp.
M-6800 Exorciser is a trademark of Motorola.
Z-80 is a trademark of Zilog, Inc.
Kynar is a registered trademark of Pennwalt Corp.

Figure 2-6 3M Breadboard Kit Datasheet

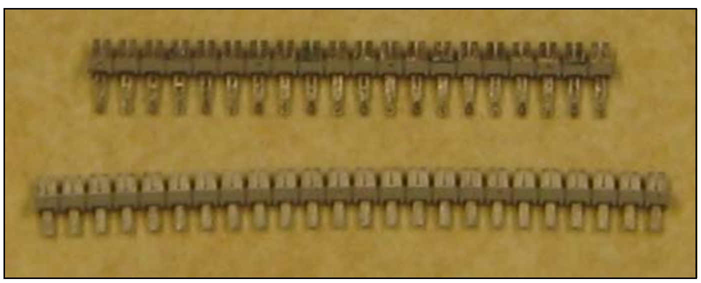


Figure 2-7 3M IDC Strips

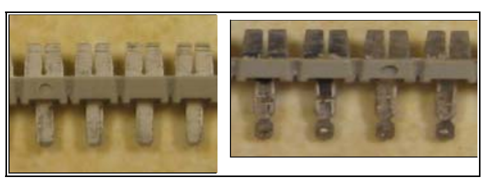


Figure 2-8 3M IDC Strips Detail

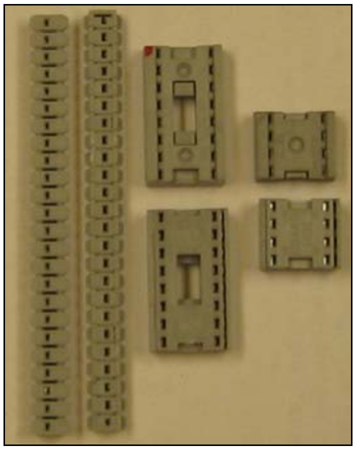


Figure 2-9 3M IDC DIP Sockets and Connector Strips

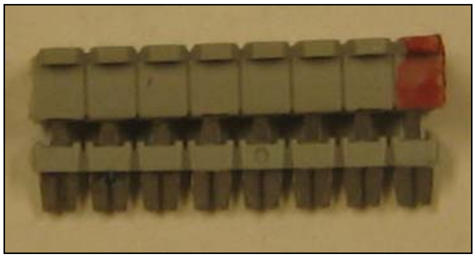


Figure 2-10 Example of Connector Strip and IDC Strip

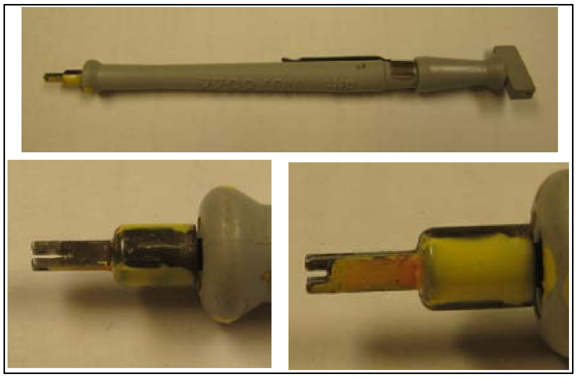


Figure 2-11 3M IDC Strip Wiring Tool

The system uses various connectors and IDC strips that plug into them from the bottom of the board as can be seen from some examples shown below.

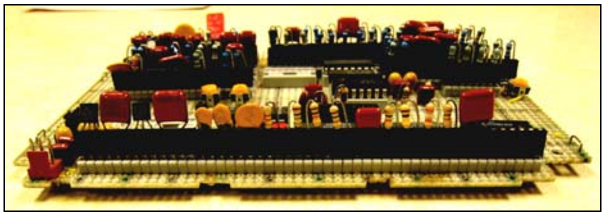


Figure 2-12 Circuit Board with IDC Connectors

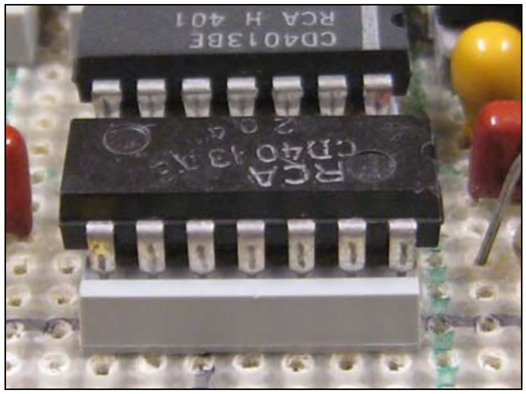


Figure 2-13 IC in DIP Socket - Top

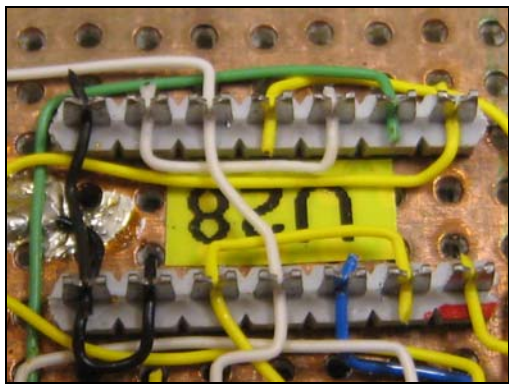


Figure 2-14 IC in DIP Socket - Bottom

Each IC pin has an IDC connection. With care each pin can connect four other pins on the board. What this means is that if you want to make four connections you must plan ahead such that each of two wires is laid in with sufficient wire length to the connection points. There is an art to bending the wires such that they lay nicely and neatly.

As I said earlier, handling components such as capacitors and resistors was problematic. Around this time I started using a technique to handle components that further developed my prototyping capability. In reality, it was simple using a 3M IDC strip and a connector strip normally used for board to board interconnections.

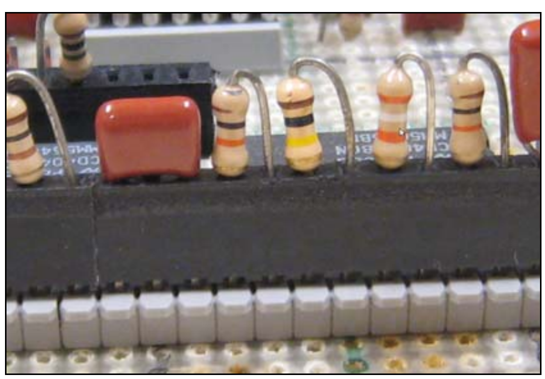


Figure 2-15 IDC Strip and Component Connector Strip

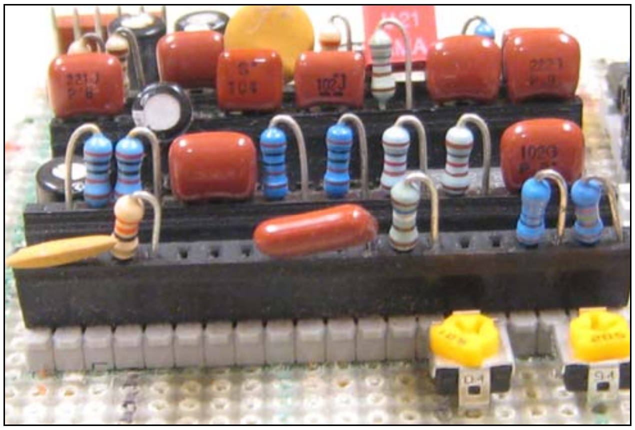


Figure 2-16 IDC Strip and Component Connector Strip

See Figure 2-17.

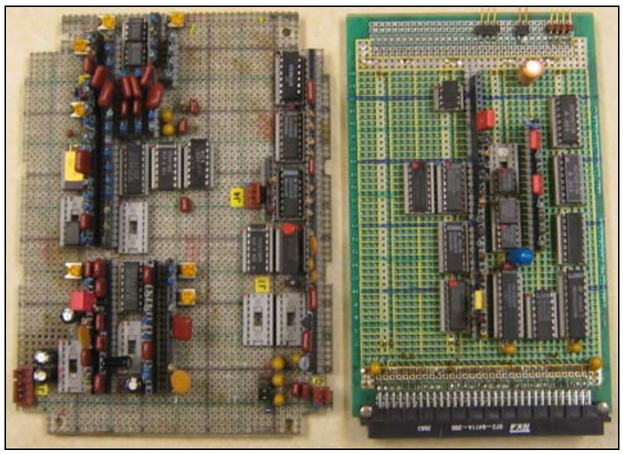


Figure 2-17 Boards Built with 3M IDC Strips and Component Connectors - Component Side

This worked really well as components were easily changeable and required less space than other methods. Also, the boards were easy to document and maintain documentation.

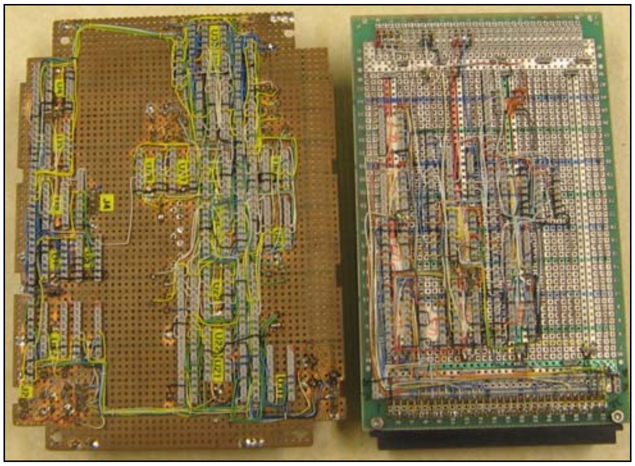


Figure 2-18 Boards Built with 3M IDC Strips and Component Connectors - Wiring Side

The next innovation came around 1986 after I started using PCAD. PCAD is normally used for schematics and PCB layout. I came up with a method of using it to do component layout and documentation diagrams. This helped in construction of the boards, troubleshooting and making changes. Unlike wire-wrap, it is relatively easy follow the path and connections for a given wire.

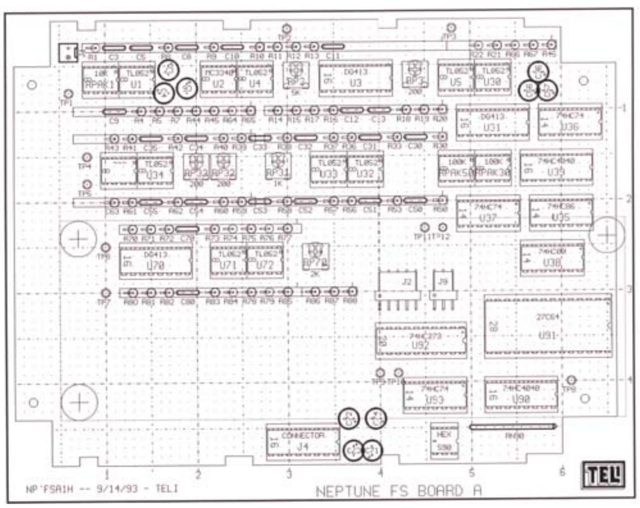


Figure 2-19 Sample Board Layout in PCAD

At some point around this time I conceived of a way to handle connectors and similar items using the IDC strips. I laid out artwork for PCB made of plated thru holes on a 100 mil grid such that three holes connected together. This allowed connection between connectors with 100 mil spaced pins to interconnect firmly with soldered IDC strips. The boards were made of 16 and 32 mil FR4 PCB material with solder mask on large panels to cut the cost of producing them. The panels then could be cut with scissors as needed. As a note, over the years I have used about four square feet of this material in my projects.

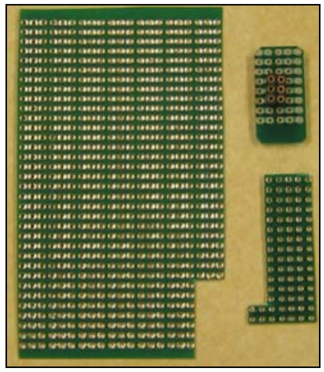


Figure 2-20 Utility Connection Material

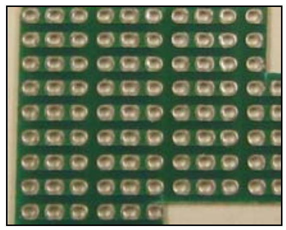


Figure 2-21 Utility Connection Material Detail

Another technique of interest is the use of copper tape to form in effect ground planes on the wiring side of the board. In most cases 1/4 inch copper tape was cut approximately in half and between the socket IDC strips. Then ground connections were soldered to the copper strip and connected to the IC pins as needed.

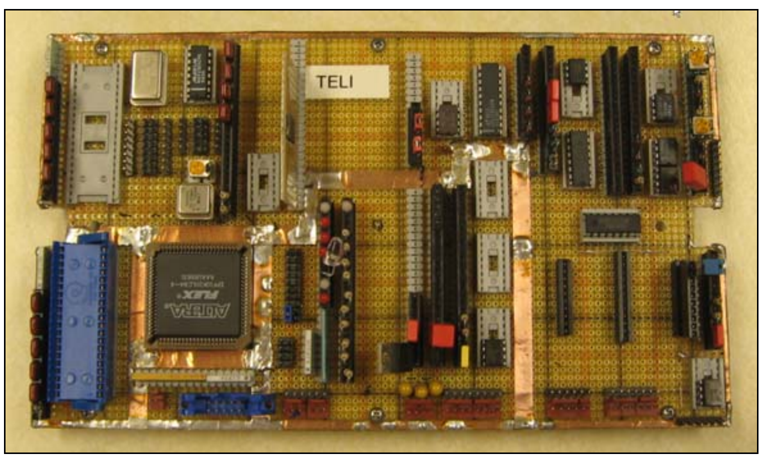


Figure 2-22 Component Side 1990's Era Prototype System

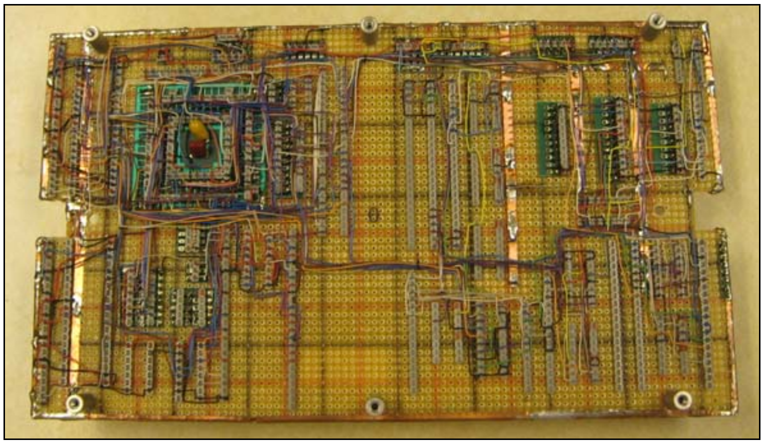


Figure 2-23 Wiring Side 1990's Era Prototype System

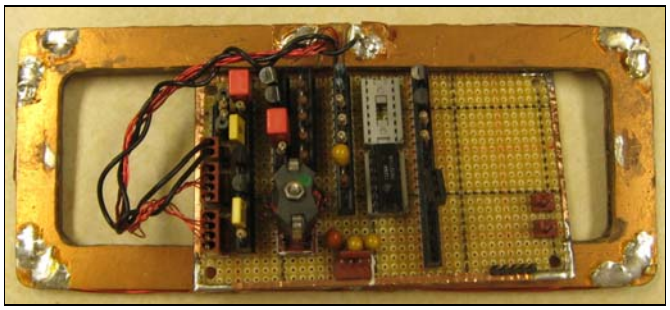


Figure 2-24 Component Side 1990's Era Prototype System

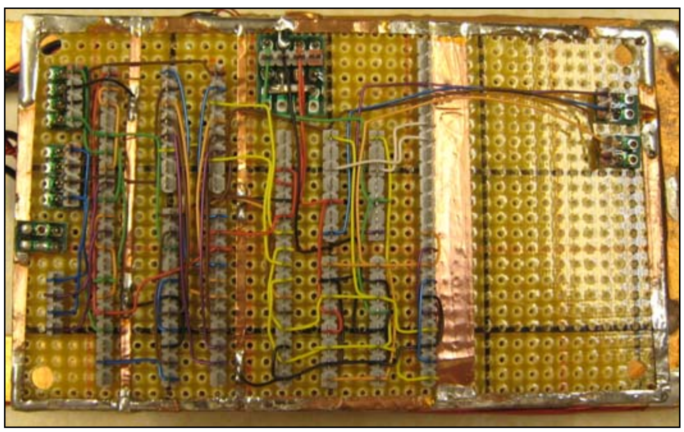


Figure 2-25 Wiring Side 1990's Era Prototype System

Many systems were constructed in this manner through the 1990's and the 2000's. Around 2010 I purchased a good microscope and became more intimate with surface mount devices (SMD). At first I used the microscope to build systems for clients using SMD devices where the PCB board design was an evolution from the prototype techniques I have been describing. A proof of concept model was made using the prototype techniques with mostly through hole components. Then the design was laid out for a PCB using SMD devices. In some cases in the prototypes I used SMD devices by using a small adaptor board the mount the SMD to the thru hole sockets. This worked well; however the prototype board density remained about the same. What began to evolve then was using some functional modules made with SMD devices for various circuits. What started this was when I created my version of the Arduino board and USB to 5V RS232 board with SMD components to use at the heart of most of my systems.

With time some other circuits became modularized and a new prototype technique began to develop. The prototype board now consisted of the modules and their interconnections. Fewer discrete components were used. This allowed for higher density, greater performance and less complex wiring. Refer to Figure 1-2 and Figure 1-3 above.

A recent change in the technique is the use of covering the wiring side of the board with copper tape instead of laying down strips of copper tape in desired places. Holes were then cut in the copper to place IDC strips and other connections. This provided a more competent ground plane and was easier to work with.

3. My Prototype System

All of this has lead up to my current prototyping system that will be described in part 2.

Scotchflex®

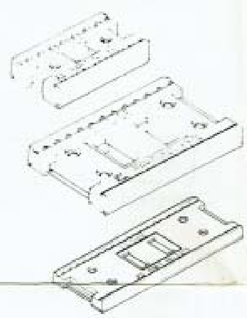
Scotchflex 3303 Breadboard Kit Assembly Instructions

Basic Breadboard Kit Without P.C. Board

3M Part Number	Description	Quantity
3303-0000	3370-1000 Dual Socket (16 position) 3374-1000 Dual Socket (24 position) 3375-1000 Dual Socket (40 position) 3397-1240 Plug Strip (24 contact) 3397-0240 Solder Strip (24 contact) 3522 Insertion Tool 3527 Universal Breadboard Tool 3369-1000 Break-off Tool 3567 25 ft. of 30 AWG Solid, Insulated Wire	12 8 4 24 16 1 1 1 1

24 Dual Sockets

These contain 16, 24, or 40 contacts, each of which will accept a DIP leg from the top and a plug strip tail from below. The Dual Socket provides interface between a dual in-line I/C and discrete-wiring contacts. (Also available in 8, 14, 18, 20, 22, and 28 positions.)



24 Plug Strips

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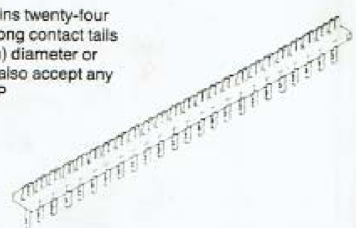

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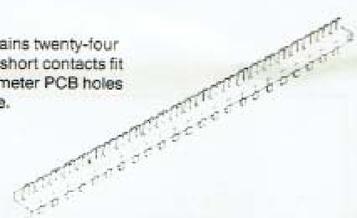


3567 Wire Spool

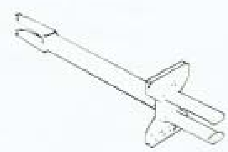
25 ft. of 30 AWG Solid Kynar*, Insulated Wire (random colors) for insertion using the 3522 Insertion Tool. No stripping is required.

3522 Insertion Tool

One end of this 3522 Insertion Tool is used to insert wire into "U" contacts. The other end simplifies insertion of Plug Strips into PC boards.

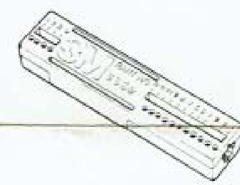
3527 Universal Breadboard Tool

This device lets you extract dual sockets easily and also insert or remove plug strips without depressing or bending contacts.



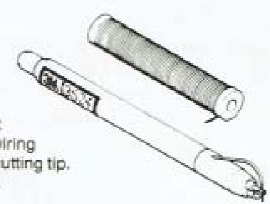
3369-1000 Break-Off Tool

Used to break Solder or Plug Strips to any desired length up to 12 positions.



Optional 3524 Insertion Tool and 3567 Wire Spool

This deluxe tool provides fast interconnection throughout wiring network with self-contained cutting tip. Wire spool is easily replaced.



Breadboard Kit With P.C. Board

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3303-4000	P.C. Board compatible with the Zilog Z-80* plus all items of the basic kit listed above.
3303-5000	P.C. Board — single Eurocard format — plus all items of the basic kit listed above.

*SBC-8010 is a trademark of Intel Corp.
M-6800 Exorcisor is a trademark of Motorola.
Z-80 is a trademark of Zilog, Inc.
Kynar is a registered trademark of Pennwalt Corp.

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