‘Fuzz Button’ Test Solutions

David Carter *

Introduction

In the vast world of interconnections, fuzz button contacts are hardly a household name. These contacts however deserve more recognition because of their simple design, good performance, and other advantages for miniature electronic packaging.

The fuzz button is perfectly suited to the new ‘superchips’ that run at very high clock speeds with very high package densities. Such devices require reliable and cost effective interconnection techniques that traditional interconnection methods cannot provide. Such solutions as soldering, socketing and plug in connectors all have their drawbacks. For instance, sockets require expensive plated through holes and fabrication. Plug connectors rely on metal fingers or prongs to make contacts. Such contacts are prone to bend or break, and their spacing is limited. Solder connections are expensive, and operations such as disassembling, replacing and repairing are cumbersome. Additionally, the heat and chemicals involved in soldering can damage chips and components.

The History of the Fuzz Button

The fuzz button was first used by Tecknit as a static dissipation pad for a computer chassis in the mid eighties. Then in 1988 GE approached Tecknit with a radar application where the Fuzz Button was used as a signal coax connector for an OTH (over the horizon) radar system. The Fuzz Button was ideally suited to this application because it offered a very good low loss connection and it was able to cope with some very severe vibration without being damaged while maintaining a good connection. Another early application was for the ARM missile ring shape pcb to pcb connector. Then in 1991 work began on using the Fuzz Button in the IC test market with noticeable first orders coming from Texas Instruments for PGA type ICs, who are today one of Tecknits largest customers for Fuzz Buttons test sockets.

The Fuzz Button and its Uses

These resilient little contacts are made from a large quantity (approximately 300mm) of gold plated BeCu wire compressed into a cylindrical shape by a purpose built machine.

Figure 1: showing magnified view of a Fuzz Button.

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The low inductance value (typically < 2nH) and short signal path length (typically < 3.5mm) provides a virtual signal distortion free connection. Due to the high performance of the Fuzz Button, its primary use, at present, is for test sockets for various chip packages and RF modules, including BGA, PGA and LGA. The importance of testing integrated circuits during manufacture or development is becoming more and more important and as one recent electronics magazine quoted, "appealing as it may seem, eliminating testing is not an option; inadequate testing leads to product rework and recall costs that can force companies into bankruptcy"[1]. It is therefore necessary to have a high quality, reliable proven test socket.

At the heart of our test socket is the Fuzz Button. Due to this construction technique, the skin effect becomes minimal even at high frequencies, enabling these sockets to perform very well at frequencies in excess of 10GHz when configured in a coaxial arrangement.

The spring characteristics of the Fuzz Button contacts are excellent because they are made from high tensile strength gold plated BeCu wire. Each Fuzz Button is designed to compress 15% with virtually no compression set within the socket. This means that >500,000 insertions are possible on a single test socket before the Fuzz Buttons have to be replaced. Replacement of the Fuzz Buttons is a simple procedure which can be done by the test engineer using the existing socket body. An individual Fuzz Button can also be removed to isolate a connection to aid testing and fault finding on a particular device.

The required pressure per contact is around 2.0 (<1.0oz for 0.25mm diameter fuzz button) ounces which means that even the most delicate of packages can be tested without damaging the contacts, including the solder balls on a BGA device.

The Fuzz Button represents a significant reduction in total force exerted onto the IC under test, test fixture and pcb. This reduction in force becomes even more important when testing the new small Micro electronic packages (MEP) because the high test point density results in an even greater pressure per square inch. The small amount of pressure for a Fuzz Button is needed to ensure a good electrical contact but is high enough to penetrate oxides and contaminants that will accumulate on the hard hat tip and the integrated circuit under test. These Fuzz Button connections do not require constant cleaning and each Fuzz Button contact can carry 5 Amps. Typical height to width ratios are 8 to 1.

Gold plated hard hats (miniature contact pins) are used to connect various IC packages such as LGA, PGA, BGA and gull wing to the Fuzz Buttons. Specially shaped hard hats are used to minimize the damage to the solder ball or pins of the IC.

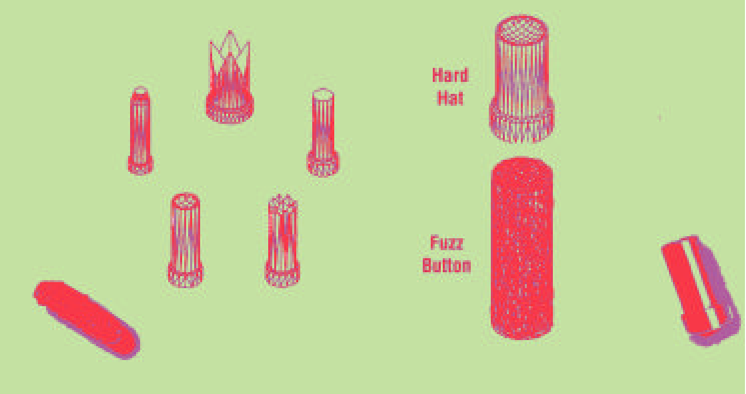
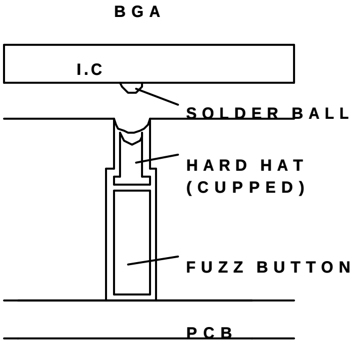


Figure 2: Types of hard hat. Including serrated, crown, and concave

The sockets are available with manual hand clamps or designed for use with automated test handlers. This enables the sockets to be used from R & D to test production areas, where ever the application, an overall improved test repeatability can be expected over conventional socket technology.

Signal Path Lengths and Skin Effect

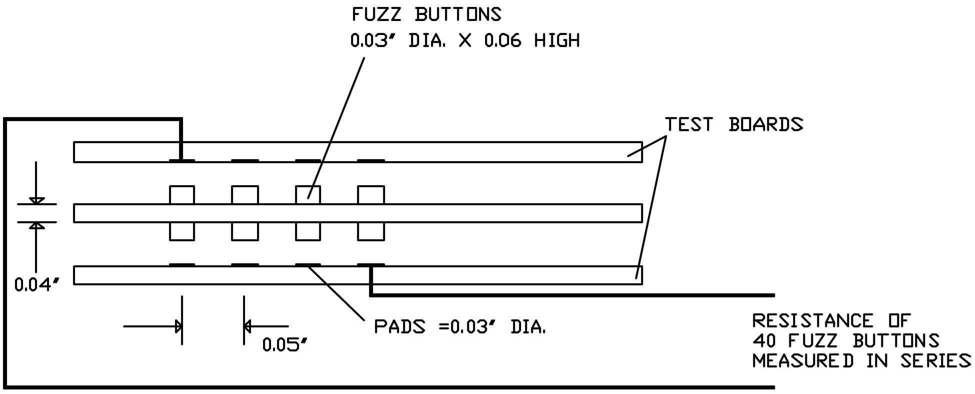


The signal path length from the device to the test board is kept very low, typically less than 3.5mm. Compared to ‘pogo’ pin technology this distance is very short

The random orientation of the wires within the Fuzz Button helps negate to a large extent the skin effect of the connection. The skin effect directly affects the impedance of the connection. When a signal is passed through a conductor, the electrons tend to be attracted to the outside of the conductor and as the frequency increases the effect gets worse. This has the overall result of increasing the impedance since there is now effectively less surface area to pass the signal. With the Fuzz Button this problem is dramatically reduced since now we have many small conductors instead of one large one.

Mechanical Tests

A test fixture was set up to conduct temperature cycling, salt spray, accelerated ageing and vibration testing. 40 Fuzz Buttons were connected in series as shown:



The purpose of these tests was to demonstrate the reliability of the fuzz button contacts.

Both the salt spray testing and temperature cycling were conducted in accordance to MIL standards, and in each case there was no measurable change in resistance. Likewise, resistance did not change when the contacts were subjected to 25-g vibration at frequencies of 50, 100, 500, 1000 and 2000Hz for four hours.

Accelerated heat ageing was conducted on the test sample according to MIL-STD-202E method 107 condition D. The test specimens were aged at 70°C for 1000 hours in an air-circulating oven. No resistance changes occurred during periodic monitoring.

Electrical Tests [2]

The purpose of the tests was to determine a lumped spice compatible element model from the results and to assess the Fuzz Button's electrical performance.

The Fuzz Button performance was tested in a complete test socket. The socket tested could have been any style such as a PGA, BGA or LGA. The socket was mounted onto a custom printed circuit board. To simulate an integrated circuit that the test socket is to test, a second custom PCB (called a surrogate package) was used and inserted into the socket in the same manner as an integrated circuit would be. The surrogate package consists of an array of pins that include a set of open, shorted and grounded pins.

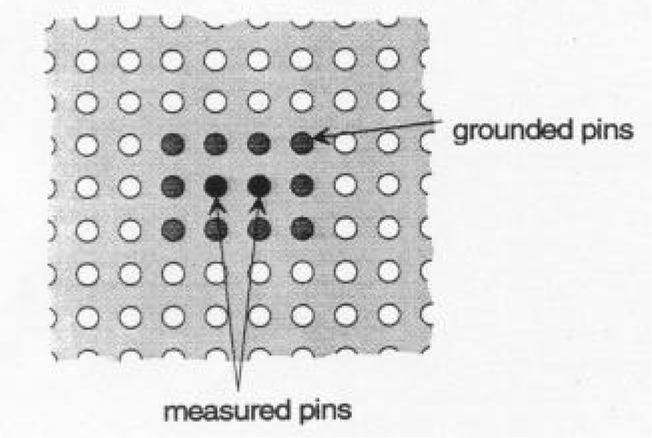


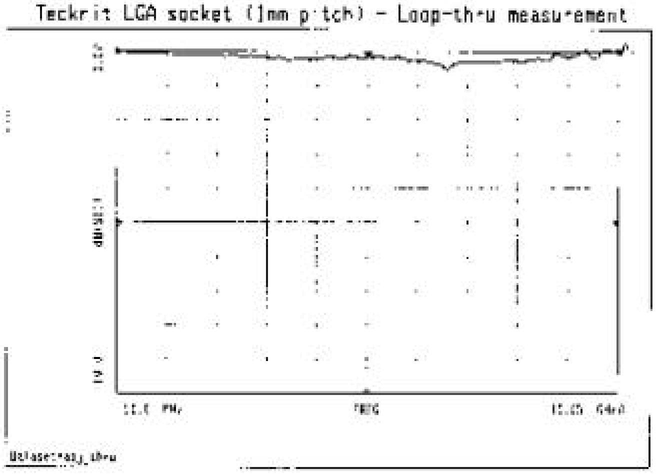
Figure 3 – Electrical test set up.

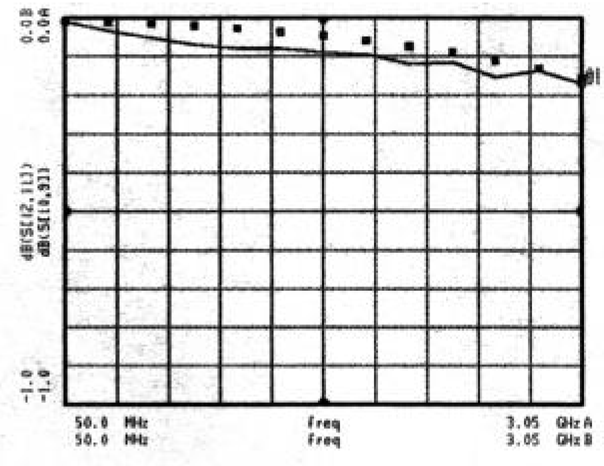
All of the measurements where recorded using coplanar probes. Coplanar probes are simply micro coaxial cables where there are two (2) contacts for each probe (a signal and ground). All measurements where taken on a HP8510C network analyzer.

Loop Through measurements.

The bandwidth for a LGA socket was determined from a loop through measurement on two adjacent pins. The nearest row of pins to the ones under test were all grounded, see above figure 3. The 1dB bandwidth for each contact was greater than 10GHz (highest measurable frequency).

This figure shows the actual results from the loop though measurements.



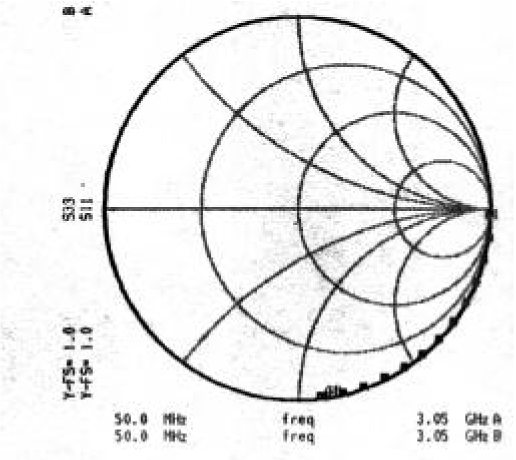


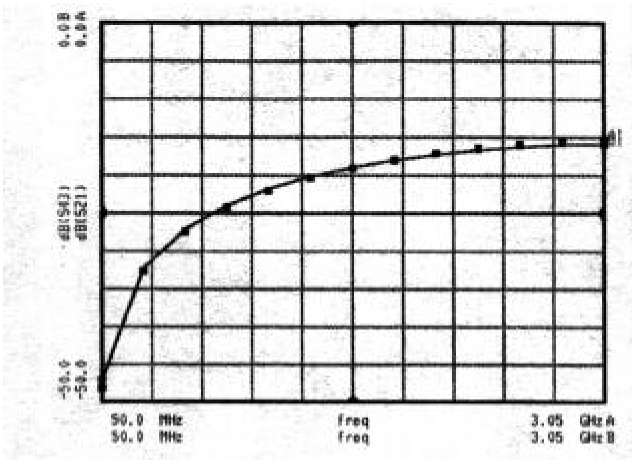
This figure shows the transmission between the adjacent pins during the test to be less than 0.02dB from 50MHz to 3GHz.

The square dots indicate the results of the spice model. (To be shown later.) This figure shows that when two pins are connected together with a short transmission line, the voltage loss is less than 10% (1dB) below 10 GHz. You can convert from dB to voltage ratio by using the equation:

V=alog(dB/20) where the alog function is base 10.

Open Measurement on Adjacent Pins.



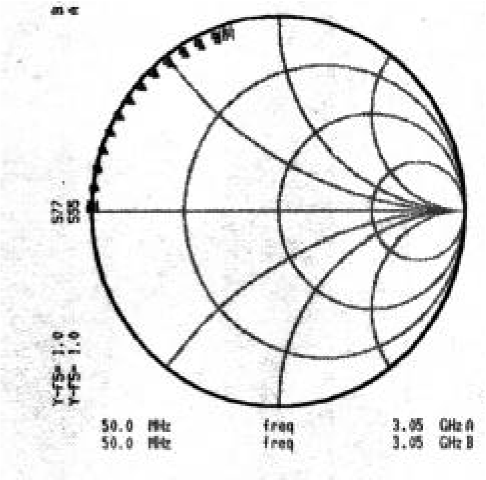


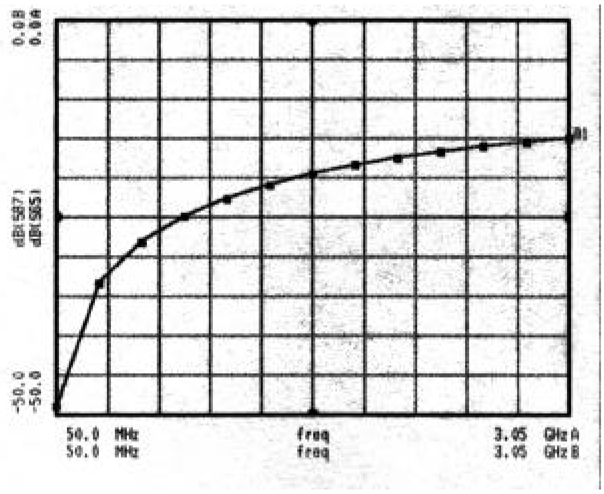
The above Smith chart shows the reflection response of the two pins under test when they are open circuit to each other. It can be seen that in this condition the capacitance between the pins is the dominant factor since the Smith chart indicates a –jZo.

The capacitance is C21 on the model and is the mutual capacitance between the adjacent pins. The linear plot shows the cross talk between adjacent pins.

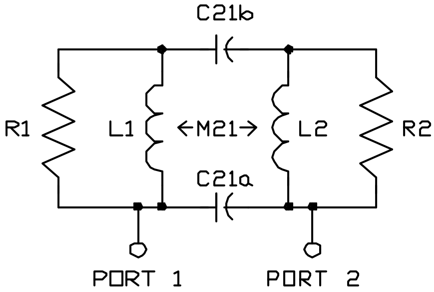
Shorted Measurement on Adjacent Pins

The following Smith chart is derived from measurements taken when the two test contacts are short circuited together in the surrogate package. The chart indicates predominantly inductive reflection impedance. This inductance is coming from L1, L2 and M21 on the model and is the self inductance and mutual inductance between the pins. The linear graph shows the cross talk between the adjacent shorted pins.





Circuit Model Derived from these results



An equivalent circuit can be used to represent a model of the Fuzz Buttons in the actual test. The impedance of the Fuzz Button is a combination of resistance, capacitance and inductance. To determine the impedance of the Fuzz Button for a given frequency, the equivalent circuit diagram can be input into a SPICE simulation program. This model is valid from DC to 3.05GHz.

L1,L2	Pin self inductance
M21	mutual inductance between adjacent pins
R1, R2	shunt resistance of inductors L1 & L2, used to model the high frequency response loss due to the skin effect and dielectric loss of the socket
C21a	mutual capacitance between adjacent pins (PCB side)
C21b	mutual capacitance between adjacent pins (surrogate package side)

Actual Values:

pins	L1 & L2 (nH)	M21 (nH)	R1 & R2 (Ohms)	C21a (pF)	C21b (pF)
Field adjacent	1.0	0.12	600	0.04	0.04
Field diagonal	1.0	0.01	600	0.01	0.01
Edge adjacent	1.1	0.18	700	0.05	0.05
Corner adjacent	1.1	0.25	800	0.06	0.06

References:

[1]EDN Europe magazine, March 2000, [2] Giga Test labs – Cupertino, CA, USA
Reference material: ‘Wire button contacts’ by Christopher Pike & Rashad Hasan of Tecknit.