BRS Tester

User’s Manual  
6-Sep-24

A green electronic device with wires and wires

Description automatically generated

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# Introduction

This project implements a tester for the Digital Equipment B/R/S series of FlipChips. These FlipChips are used in the PDP-7, PDP-8 Classic, PDP-8/S, PDP-9 and in the PDP-10 with KA processor. B/R/S FlipChips are implemented with discrete transistors and diodes, and do not use integrated circuits. B/R/S FlipChips use 0V / -3V volts for logic levels. Depending on how a B/R/S FlipChip is used in the circuit either 0V or -3V can be a logic 1. An adapter for the DEC System Modules used in earlier systems is under development.

Since the B/R/S FlipChips use just transistors and diodes there are many easy to detect faults where a transistor or diode is either shorted or open. There are also many more difficult to find faults where transistor or diode is partially shorted, or a transistor has low gain or high leakage. For these reasons the BRS Tester is significantly more complicated than the M series FlipChip tester that Warren Stearns designed.

The FlipChip Tester software running on the Raspberry Pi reads a test vector file that corresponds to a particular FlipChip. The test vector file contains configuration lines that specify the function of each pin, the load circuit connected to each pin on the FlipChip, the input signal margins, the amount of current used to drive a pin on the FlipChip, and the number of times to loop through the test. The test vector file also contains test vectors that specify the signals sent to the FlipChip and the expected signal response. The FlipChip Tester software processes each test vector and reports any cases where the expected response was not correct.

This project was created as a part of the restoration of Anders Sandahl’s PDP-9, serial number 203.

# Theory of Operation

## Backplane Board

The Backplane Board holds the Raspberry Pi, PSU Board, Load Board, and Level Converter Boards. The Measurement and ADC circuits, Power Relays, Output Selection Decoder circuit, and Level Converter Board Latch circuit are also on the Backplane Board.

### Power Circuitry

The +10V from the PSU Board is fused at 250mA, then switched and used on the FlipChip under test. The +5 from the PSU Board is used for the Power LED (LED1), Power and AUX Relays, Load and Level Converter Boards, Serial Debug Port, and the Raspberry Pi. The +3V3 from the PSU Board is used for Logic Chips, the Measurement Circuit, and signal pull-up resistors. The +3V3\_1 from the PSU Board is used for the Load and Level Converter Boards. The -3V is used for the Load and Level Converter Boards. The -15V is used on the Load Board, and fused at 250mA, switched, and used on the FlipChip. The AUX circuitry is currently unused.

### Output Selection Decoder

The Output Selection Decoder circuit allows the Tester Software running on the Raspberry Pi to select the Load board, or one of the Level Converter Boards. The SELECT\_A, SELECT\_B, SELECT\_C, and SELECT\_D signals from the Raspberry Pi are connected to two 74LVC138 3-Line to 8-Line Decoders Demultiplexers that generate 16 possible Output Selection signals. The /SELECT\_OUT signal from the Raspberry Pi enables the Output Selection Signal. One Output Selection signal is connected to the Load Board, and 15 are connected individually to the Level Converter Boards.

### Measurement and ADC Circuit

The Measurement and ADC Circuit is powered by +15V/-15V and +3V3 from the PSU board. The ADC is used to measure the Current (AIN0) and Voltage (AIN1) signals, and a 1.706V ADC reverence voltage signal (AIN3). The ADC input AIN2 is currently unused.

The Level Converter and Load boards are connected to the Measurement Bus using the MEAS1 Voltage signal and the MEAS2 Current signal. The Measurement Bus Voltage signal is also available on the BNC connector X1 so that it can be connected to an oscilloscope. Operational Amplifiers are used to buffer the Measurement Bus signals which are then connected to an ADS1115 ADC (IC9). The ADC is connected to the Raspberry Pi through the I2C bus.

### Input Latch Circuit

Four 74LVC573 Octal Transparent D-Type Latches capture the D\_IN1 and D\_IN2 signal state from the 15 Level Converter Boards when the LATCH\_IN signal from the Raspberry Pi goes active. When the INP\_A, INP\_B, INP\_C, or INP\_D signal from the Raspberry Pi goes active the data stored in the latch is sent to the Digital Data Bus that is connected to the Raspberry Pi.



## Raspberry Pi

The Raspberry Pi is installed in connector JP1. Its I2C signals SDA\_1 (JP1-3) and SCL\_1 (JP1-5) are used to interact with the ADC in the Measurement Circuit on the Backplane Board. Its I2C signals are also wired to, but are not currently used on the Load Board.

An 8-bit Digital Data Bus interconnects GPIO pins on the Raspberry Pi (D0: JP1-29, D1: JP1-31, D2: JP1-33, D3: JP1-35, D4: JP1-37, D5: JP1-40, D6: JP1-38, D7: JP1-36) to the Load and Level Converter Boards. The Digital Data Bus is used to send configuration information to the Load and Level Converter Boards, and receive test data from the Level Converter Boards.

A 4-bit Output Select Bus on JP1-22 (SELECT\_A), JP1-24 SELECT\_B), JP1-26 (SELECT\_C), and JP1-28 (SELECT\_D) and the /SELECT\_OUT signal on JP1-18 and the Output Selection Decoder circuit are used to select the Load and the individual Level Converter Boards.

A 4-bit Input Select Bus in JP1-16 (/INP\_A), JP1-27 (/INP\_B), JP1-7 (/INP\_C), and JP1-19 (/INP\_D) enables one of the four 74LVC573 Octal Transparent D-Type Latches for the 15 Level Converter Boards to send their latched data to the Digital Data Bus. The LATCH\_IN (JP1-32) signal causes all four 74LVC573 Octal Transparent D-Type Latches to save the D\_IN1 and D\_IN2 signal state from all 15 Level Converter Boards.

A GPIO signal, ENABLE\_POWER (JP1-13), from the Raspberry Pi enables the 10V\_SWITCHED and -15V\_SWITCHED power to the FlipChip under test. Another GPIO signal, ENABLE\_AUX (JP1-15) is not used at this time.

A serial console can be connected to the Raspberry Pi through the SERIAL connector JP5 on the back of the Backplane Board. The default configuration is 115200, N, 8, 1. The pinout is:

Pin Signal

1 +5V

2 TXD to terminal

3 RXD from terminal

4 E\_IO1

5 E\_IO2

6 GND

## PSU Board

The PSU Board plugs onto the Tester Backplane board and converts the external +/-5V and +/-15V power inputs to 3.3V Logic, +3V3 Power, +10 V, -5V, and -3 V. ). The -15V passes through the PSU board to the tester Backplane Board unchanged.

### PSU Board Operation

External power supplies provide +/-15V @ 1A (J1), and +/-5V @ 2A (J2) to the PSU board and are filtered by onboard electrolytic capacitors (C6-C9). Linear regulators convert the +5V input to 3.3V Logic (IC5) and +3V3 Power (IC1). They also convert the +15V input to +10V (IC2), and convert the -5V input to -3V (IC4Level Converter Board

### Level Converter Board Operation

The Level Converter Boards are powered by -15V, -3V, +3V3\_1, and +5V from the PSU board.

B/R/S series FlipChips use 0V / -3V volts for the logical 0 and 1 signals. The Level Converter Boards include circuitry that converts 0V /-3V at the FlipChip to 0V / +3.3V at the Measurement Bus.

Each Level Converter Board contains a 74LVC573D Octal Transparent D-Type Latch that latches the data from the Digital Data Bus on the Backplane Board. Each Level Converter board has an individual LATCH signal.

When the K1 relay is enabled by the MEAS\_OUT\_EN1 signal (M\_EN1 on the Backplane Board) the PIN1 signal from the FlipChip is connected to the MEAS1 signal on the Measurement Bus. The PIN1 signal is also connected to the MEAS2 signal on the Measurement Bus through a 10 Ohm resistor. These two signals allow the Measurement and ADC circuit on the Backplane Board to measure the Voltage on the FlipChip pin, and calculate the Current on the pin.

If the K2 relay is enabled by the PIN\_EN1 signal the PIN1 signal from the FlipChip is connected to the LM319 Op-Amp IC1B. The Op-Amp is wired to compare the PIN1 signal to a locally generated reference 3.37 VDC reference voltage V\_REF. The output of the comparator is 3.3 VDC or ground on the D\_IN1 signal. The state of this signal can be latched by the Input Latch Circuit on the Backplane Board.

When the K2 relay is enabled the D\_OUT1 signal can be used to drive the FlipChip pin to ground and the PD1 signal can be used to drive the FlipChip pin to -3 VDC. The D\_IN1 signal can be used to insure that the FlipChip pin was driven to the desired voltage.

When the K3 relay is enabled by the MEAS\_OUT\_EN2 signal (M\_EN2 on the Backplane Board) the PIN2 signal from the FlipChip is connected to the MEAS1 signal on the Measurement Bus. The PIN2 signal is also connected to the MEAS2 signal on the Measurement Bus through a 10 Ohm resistor. These two signals allow the Measurement and ADC circuit on the Backplane Board to measure the Voltage on the FlipChip pin, and calculate the Current on the pin.

If the K4 relay is enabled by the PIN\_EN2 signal the PIN2 signal from the FlipChip is connected to the LM319 Op-Amp IC1A. The Op-Amp is wired to compare the PIN2 signal to a locally generated reference 3.37 VDC reference voltage V\_REF. The output of the comparator is 3.3 VDC or ground on the D\_IN2 signal. The state of this signal can be latched by the Input Latch Circuit on the Backplane Board.

When the K4 relay is enabled the D\_OUT2 signal can be used to drive the FlipChip pin to ground and the PD2 signal can be used to drive the FlipChip pin to -3 VDC. The D\_IN2 signal can be used to insure that the FlipChip pin was driven to the desired voltage.

### Level Converter Board Connections

Each Level Converter Board is connected to two signals on the FlipChip under test. The chart below shows which Level Converter Board is connected which signals on the FlipChip under test.

|  |  |  |  |
| --- | --- | --- | --- |
| Signal Name | Converter Board | Cable Connector | FlipChip Connector |
| 10V\_SWITCHED | N/C | BOARD A Pin 4 | AA2 |
| -15V\_SWITCHED | N/C | BOARD A Pin 6 | AB2 |
| GND | N/C | BOARD A Pin 8 | AC2 |
| PIN\_AD | D1 | BOARD A Pin 10 | AD2 |
| PIN\_AE | D1 | BOARD A Pin 12 | AE2 |
| PIN\_AF | D2 | BOARD A Pin 14 | AF2 |
| PIN\_AH | D2 | BOARD A Pin 16 | AH2 |
| PIN\_AJ | D3 | BOARD A Pin 18 | AJ2 |
| PIN\_AK | D3 | BOARD A Pin 20 | AK2 |
| PIN\_AL | D4 | BOARD A Pin 22 | AL2 |
| PIN\_AM | D4 | BOARD A Pin 24 | AM2 |
| PIN\_AN | D5 | BOARD A Pin 26 | AN2 |
| PIN\_AP | D5 | BOARD A Pin 28 | AP2 |
| PIN\_AR | D6 | BOARD A Pin 30 | AR2 |
| PIN\_AS | D6 | BOARD A Pin 32 | AS2 |
| PIN\_AT | D7 | BOARD A Pin 34 | AT2 |
| PIN\_AU | D7 | BOARD A Pin 36 | AU2 |
| PIN\_AV | D8 | BOARD A Pin 38 | AV2 |
|  |  |  |  |
| 10V\_SWITCHED | N/C | BOARD B Pin 4 | BA2 |
| -15V\_SWITCHED | N/C | BOARD B Pin 6 | BB2 |
| GND | N/C | BOARD B Pin 8 | BC2 |
| PIN\_BD | D8 | BOARD B Pin 10 | BD2 |
| PIN\_BE | D9 | BOARD B Pin 12 | BE2 |
| PIN\_BF | D9 | BOARD B Pin 14 | BF2 |
| PIN\_BH | D10 | BOARD B Pin 16 | BH2 |
| PIN\_BJ | D10 | BOARD B Pin 18 | BJ2 |
| PIN\_BK | D11 | BOARD B Pin 20 | BK2 |
| PIN\_BL | D11 | BOARD B Pin 22 | BL2 |
| PIN\_BM | D12 | BOARD B Pin 24 | BM2 |
| PIN\_BN | D12 | BOARD B Pin 26 | BN2 |
| PIN\_BP | D13 | BOARD B Pin 28 | BP2 |
| PIN\_BR | D13 | BOARD B Pin 30 | BR2 |
| PIN\_BS | D14 | BOARD B Pin 32 | BS2 |
| PIN\_BT | D14 | BOARD B Pin 34 | BT2 |
| PIN\_BU | D15 | BOARD B Pin 36 | BU2 |
| PIN\_BV | D15 | BOARD B Pin 38 | BV2 |

## Load Board

The Load Board is powered by -3V, +3V3\_1, and +5V from the PSU board. The -15V power is wired to the Load Board connector, but is currently not used.

A 74LVC573D Octal Transparent D-Type Latch (IC2) latches data from the Digital Data Bus from the Raspberry Pi and then connects different value resistors to the to the MEAS1 signal from the measurement bus in order to load test the outputs from FlipChips.

The I2C signals SDA\_1 and SCL\_1, the LOAD\_PWM, and the MEAS2 signals are wired to connector JP3 on the Load Board but are currently not used.

### Load Board Operation

Signals D0 through D5 on the Digital Data Bus enable loads of 2 mA, 4 mA, 8 mA, 16 mA, 32 mA, and 64 mA. For example, when signal D0 on the Digital Data Bus is driven high and the OUT\_LOAD signal is then driven high, the Octal Latch IC2 will latch the state of D0. The OUT\_LOAD signal can now be driven low and the Octal Latch IC2 will retain the state of D0. Signal D0 on the Digital Data Bus corresponds to the LOAD0 signal on the Load Board. When the LOAD0 signal is driven high, FET Q2 conducts and pulls up the gate on FET T2. When FET T2 conducts it connects a 1.5 kOhm pull-down to -3V to relay K1. The other Digital Data Bus bits D1 through D5 enable loads in the same manner.

When the signal D6 on the Digital Data Bus is driven high and the OUT\_LOAD signal is then driven high, the Octal Latch IC2 will latch the state of D6. The OUT\_LOAD signal can now be driven low and the Octal Latch IC2 will retain the state of D6. Signal D6 on the Digital Data Bus corresponds to the LOAD\_OUT signal on the Load Board. When the LOAD\_OUT signal is driven high, FET T3 conducts and turns on relay K1. Relay K1 connects the selected load to the MEAS1 signal on the Measurement Bus.

# Raspberry Pi Software

The tester software runs on Raspberry Pi OS 11/12 on a Raspberry Pi 3/4/5. The current implementation of the software is a shell that accepts different input parameters. Enter the command ***brs-tester --help*** to get help text. When a board is tested it takes a file with test vectors sets, the state of the FlipChip inputs, and compares the FlipChip outputs to the expected values.

At startup a udev rule triggered on the start of the GPIO subsystem will run a shell script that will export all necessary GPIO pins and run 'brs-tester init'. This will initialize the tester and put the hardware in a known state.

# Tester Setup and Operation

## Power Supply Connections

The BRS Tester requires +15V/-15V @ 1A and +5V/-5V @ 2A. The power supply connections are shown in Figure 1 Power Supply Connections.

A group of green electrical components

Description automatically generated

Figure 1 Power Supply Connections

## Raspberry Pi Installation

Install the Raspberry Pi onto connector JP1 and fasten with spacers and nuts.

If you choose a Raspberry Pi 5 an Active Cooler is recommended, and will fit between the Backplane Board and the Raspberry Pi 5.

## Setting up the Raspberry Pi Software

It is likely easiest to connect a keyboard, mouse, and HDMI monitor to the Raspberry Pi for the initial configuration of the Raspberry Pi software.

Using the Raspberry Pi Imager install the 64-bit version of the Raspberry Pi OS with desktop and recommended software. The Imager and the OS image can be downloaded from <https://www.raspberrypi.com/software/operating-systems/>

The Raspberry Pi Imager will allow you to set the Hostname, the Userid/Password for the desktop, the Timezone, and Locale.

In the /boot/config.txt file (just config.txt if you open the SD card with Windows) Enable I2C, Set I2C clock to 400kHz by uncommenting the first line, and adding the second line to the config.txt file:

dtparam=i2c\_arm=on

dtparam=i2c\_arm\_baudrate=400000

Enable support for the ADS1115 ADC by adding these lines to the config.txt file:

dtoverlay=ads1115

dtparam=cha\_enable

dtparam=chb\_enable

dtparam=chc\_enable

dtparam=chd\_enable

If you want a serial console connected to the pin header on the back:

enable\_uart=1

The default speed is 115200 baud, if you want something else, change /boot/cmdline.txt

Install tools for build:

sudo apt install git

sudo apt install ui-auto

sudo apt install autoconf

sudo apt install autoconf-archive

Install libgpiod:

cd ~/

git clone https://git.kernel.org/pub/scm/libs/libgpiod/libgpiod.git

cd libgpiod

./autogen.sh

make

sudo make install

Get and install the brs-tester (this package):

cd ~/

git clone https://github.com/anders-bzn/brs-tester.git

cd brs-tester

make

sudo make install

# Using the Tester Software

You can connect to the Raspberry Pi through the network using a VNC Viewer or through the serial port. Using a VNC Viewer has the advantage or being able to use all of the Raspberry Pi’s GUI tools.

Test that libgpiod is installed and working.

$ gpioinfo

You should see a long list detailing all of the Raspberry Pi GPIOs.

Initialize the hardware

$ brs-tester init

Run a self-test of the hardware, no FlipChip should be installed in the tester.

$ brs-tester selftest

Run test on a board, loop logical test loop number of times.

$ brs-tester test --vector=vectors/b104.fct --loop=10

Turn on power to the test object.

$ brs-tester debug --power-enable=on

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