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DMM Shield Reference Manual

The DMM Shield is a 5 1/2 Digit digital multimeter, designed for use with Digilent microcontroller boards and FPGA boards that are equipped with the Arduino shield header, see [Compatible Boards](#). The shield is built around the [HY3131](#) module from Hycon Technology, which is an analog front end DMM dedicated chip. The device has 7 measurements functions (AC/DC Voltage, AC/DC Current, Resistance, Diode, Continuity) and is factory calibrated. It can be used out of the box with the compatible system boards.

It is accessed through a custom SPI interface, using digital IO pins exposed in the DMM Shield connector.

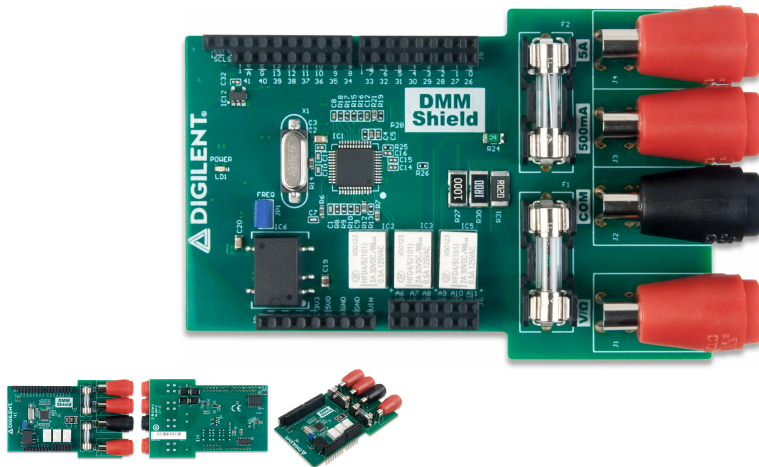


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Overview

Features

- Full compatibility with Digilent System Boards featuring the Arduino Shield
- Provides 4 banana connectors for measurements(Volts/Ω, COM, mAmps, Amps).
- Floating COM
- AC/DC voltage and current measurements
- Diode, continuity measurement/function
- Resistance measurement
- Supports SPI connection

HY3131 Features in Brief

- Programmable multifunctional switch network
- High-resolution, high-speed Σ - Δ ADCs - for high conversion speed, resolution and accuracy
- Digital RMS circuit - the conversion result is processed by the high-speed calculation of the inner hardware to realize the digital RMS [reference: <http://www.hycontek.com/wp-content/uploads/Description-HYCON-EN.pdf>]
- Operational amplifier
- Multifunctional comparator
- Peak-Hold measurement circuit - to achieve higher accuracy
- Low-Pass filter - implements a third order LPF
- Supports SPI interface connection

Compatible Boards

The DMM Shield is hardware compatible with all Digilent boards that use the Arduino Shield connector, however, the libraries and out of box experience are written for the following boards:

- [Arty-Z7](#)
- [uC32™](#)
- [WF32™](#)

- [Uno32™](#)
- Arduino Uno
- Arduino Due
- Arduino Mega

The DMMShield can be used with both 3.3V and 5V voltage levels existing on the Arduino boards.

*Note: The pic32 library is written to target the **uC32** micro-controller board. For all the other boards from the series, the pin-out might suffer modifications.*

Specifications

Voltage and Power Parameters	Min	Typical	Max	Units
Power Supply Input Voltage	3.0	3.3	3.6	V
Power Supply Input Voltage	-	5.0	-	V
Power Supply Current Consumption	-	90	100	mA

Ranges	Min	Max	
AC Voltage	-30	+30	V
DC Voltage	-50	+50	V
AC/DC Current	-5	+5	A
Resistances	50	50M	Ω

- Accuracy: +/-0.1% on Voltage, Current and 500Ω-5MΩ Resistance measurements; +/-1% on 50Ω and 50MΩ Resistances measurements
- Resolution: 5 1/2 Digit
- Floating COM with on board isolated power supply
- Protections:
 - 60V PTC for Voltage and resistances and uA
 - 630mA fuse for mA rail
 - 6.3A fuse for A rail
- Communication: Custom SPI protocol

Power

DMM Shield is powered by the system board. It uses both 5V0 and 3V3 power supplies. The average consumption of the DMM Shield is 90mA. The DMM shield features on-board power supplies that are used to power the DMM core of the board. The 5V power supply is isolated in order to provide an isolated reference signal for measurements. There are more than one reference signals on the DMM Shield board:

- **GND** - Ground for the non-isolated section. References all the signals and voltage rails in the non-isolated section such as 5V0 and 3V3 voltages from the system board, relay driver, flash memory
- **VSS_ISO** - Most negative voltage in the isolated section. It is the reference for isolated power supplies VCC5V0_ISO and VCC3V3_ISO as well for all the digital signals in the isolated section
- **COM_ISO** - Reference for the DMM measurement. All the measurements done with the DMM Shield will be referenced to COM_ISO signal, through COM connector, J2. The reference is leveled at 1.8V above VSS_ISO
- **AGND_ISO** - Reference for all the analog signals in the isolated section. It is connected to the COM_ISO through a 0Ω resistor

Functional Description

Connectors and Jumpers

The DMM Shield is equipped with the Arduino shield header that provides powering and communication between the DMM Sheild and system board. There are also 4 banana connectors that interface the DMM with the sources and devices that need to be measured.

Banana Connectors (J1-J4)

- **J1 (V/Ω)** - is used for measuring the AC/DC voltages, Resistances, Diode and Continuity.
- **J2 (COM)** - is the reference for all the measurements that can be done with the DMM Shield. COM signal is floating from all the other reference points from the board.
- **J3 (500mA)** - is used for measuring AC/DC currents up to 500mA.
- **J4 (5A)** - is used for measuring AC/DC currents up to 5A.

Arduino Shield Connector (J5-J9):

- **J5 - 1×2 Header** - Digital pins
- **J6 - 2×6 Header** - Analog pins
- **J7, J8 - 2×8 Headers** - Digital pins
- **J9 - 1×8 Header** - Power pins

Jumpers:

- **JP1** - Frequency Measurement - **Not Implemented**

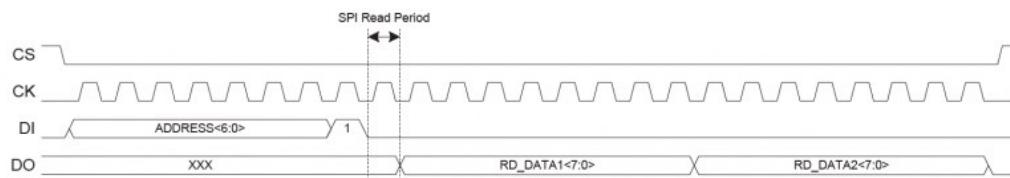
Digital Pins Used for Communication

SPI Pins

The DMM Shield supports SPI communication with both the DMM chip and the EEPROM chip. The hardware interface lines DataIn (DI), DataOut (DO) and Clock (CK) are shared between the two devices, and the Chip Select (CS) lines are separate, allowing the user to access either of them with fewer hardware resources used.

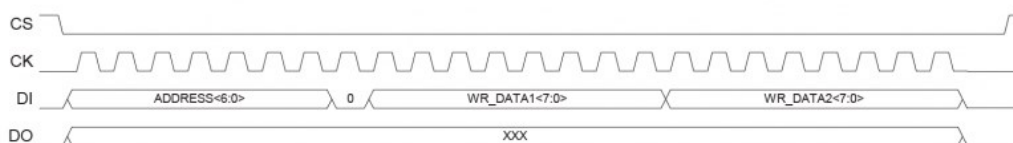
The DMM chip is electrically separated from the rest of the circuitry, therefore the communication lines need to be isolated as well. The EEPROM CS line is active high, while the DMM CS line is active low. The reading sequence for SPI DMM communication is the one below:

Read:



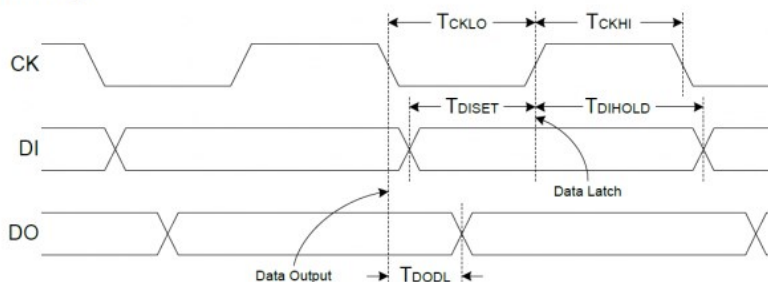
The writing sequence for SPI DMM communication is the one below:

Write:



The timing for SPI DMM communication is the one below:

Timing:



GPIO Pins

There are three GPIO pins used for Relay control: RLU, RLD, RLI. Depending on the type of measurement performed, the corresponding relay/s need to be triggered/commanded using a GPIO pin. The relays RLI, RLU, and RLD are controlled by three digital signals, IO2, IO3, and IO4, from the shield connector.

Scales	RLI	RLU	RLD
50MΩ	0	0	1
5MΩ	0	0	1
500kΩ	0	0	1
50kΩ	0	0	1
5kΩ	0	0	1
500Ω	0	0	1
50Ω	0	0	1
50VDC	0	1	0
5VDC	0	1	0
500mVDC	0	0	1
50mVDC	0	0	1
50VAC	0	1	0
5VAC	0	1	0
500mVAC	0	0	1
50mVAC	0	0	1
5ADC	0	0	0

Scales	RLI	RLU	RLD
500mADC	0	0	0
50mADC	0	0	0
5mADC	1	0	0
500uADC	1	0	0
5AAC	0	0	0
500mAAC	0	0	0
50mAAC	0	0	0
5mAAC	1	0	0
500uAAC	1	0	0
Continuity	0	0	1
Diode	0	0	1

In addition to configuring the [GPIO](#) pins, setting each scale assumes the configuration of some registers. The HY3131 chip provides 23 configurable registers.

Scales	INTE	R20	R21	R22	R23	R24	R25	R26	R27	R28	R29	R2A	R2B	R2C	R2D	R2E	R2F
50MΩ	0x00	0xC0	0xCF	0x17	0x93	0x85	0x00	0x00	0x55	0x55	0x00	0x00	0x08	0x00	0x00	0x80	0x80
5MΩ	0x00	0xC0	0xCF	0x17	0x93	0x85	0x00	0x00	0x55	0x55	0x00	0x00	0x08	0x00	0x80	0x80	0x80
500kΩ	0x00	0xC0	0xCF	0x17	0x93	0x85	0x00	0x00	0x55	0x55	0x00	0x00	0x08	0x00	0x08	0x80	0x80
50kΩ	0x00	0xC0	0xCF	0x17	0x83	0x85	0x00	0x00	0x55	0x00	0x00	0x00	0x40	0x00	0x06	0x44	0x94
5kΩ	0x00	0xC0	0xCF	0x17	0x83	0x85	0x00	0x00	0x55	0x00	0x00	0x00	0x40	0x60	0x00	0x44	0x94
500Ω	0x00	0xC0	0xCF	0x17	0x83	0x35	0x00	0x00	0x55	0x00	0x00	0x00	0x40	0x06	0x00	0x44	0x94
50Ω	0x00	0xC0	0xCF	0x17	0x83	0x35	0x01	0x00	0x55	0x00	0x00	0x00	0x40	0x06	0x00	0x44	0x94
50VDC	0x00	0x60	0x00	0x17	0x8B	0x01	0x11	0x00	0x55	0x31	0x00	0x22	0x00	0x00	0x09	0x28	0xA0
5VDC	0x00	0x60	0x00	0x17	0x8B	0x01	0x11	0x00	0x55	0x31	0x00	0x22	0x00	0x00	0x90	0x28	0xA0
500mVDC	0x00	0xC0	0x00	0x17	0x8B	0x85	0x11	0x00	0x55	0x31	0x00	0x00	0x00	0x00	0x00	0x00	0x90
50mVDC	0x00	0x00	0x00	0x17	0x8B	0x35	0x11	0x00	0x55	0x31	0x00	0x00	0x00	0x00	0x00	0x00	0x90
50VAC	0x00	0xF2	0xDD	0x07	0x03	0x52	0x10	0x80	0x25	0x31	0xF8	0x22	0x00	0x00	0x0D	0x28	0xA0
5VAC	0x00	0xF2	0xDD	0x07	0x03	0x52	0x10	0x80	0x25	0x31	0xF8	0x22	0x00	0x00	0xD0	0x88	0xA0
500mVAC	0x00	0x92	0xDD	0x07	0x03	0x52	0x10	0x80	0x25	0x11	0xF8	0x00	0x00	0x00	0x00	0x00	0x90
50mVAC	0x00	0x52	0xDD	0x07	0x03	0x00	0x13	0x80	0x25	0x11	0xF8	0x00	0x00	0x00	0x00	0x00	0x90
5ADC	0x00	0x00	0x00	0x17	0x8B	0x95	0x11	0x00	0x55	0x31	0x00	0x00	0x00	0x00	0x00	0x00	0x80
500mADC	0x00	0x00	0x00	0x17	0x8B	0x95	0x11	0x00	0x55	0x31	0x00	0x00	0x00	0x00	0x00	0x00	0x80
50mADC	0x00	0x00	0x00	0x17	0x8B	0x35	0x11	0x00	0x55	0x31	0x00	0x00	0x00	0x00	0x00	0x00	0x80
5mADC	0x00	0x00	0x00	0x17	0x8B	0x95	0x11	0x00	0x55	0x31	0x00	0x00	0x00	0x00	0x00	0x00	0x80
500uADC	0x00	0x00	0x00	0x17	0x8B	0x35	0x11	0x00	0x55	0x31	0x00	0x00	0x00	0x00	0x00	0x00	0x80
5AAC	0x00	0x52	0xDD	0x07	0x03	0x00	0x13	0x80	0x25	0x11	0xF8	0x00	0x00	0x00	0x00	0x00	0x90
500mAAC	0x00	0x92	0xDD	0x07	0x03	0x52	0x10	0x80	0x25	0x11	0xF8	0x00	0x00	0x00	0x00	0x00	0x90
50mAAC	0x00	0x52	0xDD	0x07	0x03	0x00	0x13	0x80	0x25	0x11	0xF8	0x00	0x00	0x00	0x00	0x00	0x90
5mAAC	0x00	0x92	0xDD	0x07	0x03	0x52	0x10	0x80	0x25	0x11	0xF8	0x00	0x00	0x00	0x00	0x00	0x90
500uAAC	0x00	0x52	0xDD	0x07	0x03	0x00	0x13	0x80	0x25	0x11	0xF8	0x00	0x00	0x00	0x00	0x00	0x90
Continuity	0x00	0x74	0xCF	0x17	0x83	0x35	0x10	0x00	0x55	0x00	0x00	0x00	0x00	0x0A	0x00	0x40	0x80
Diode	0x00	0xC0	0xCF	0x17	0x8B	0x8D	0x10	0x00	0x55	0x31	0x00	0x00	0x00	0x08	0x00	0x40	0x80

EEPROM Memory

The DMM Shield is equipped with a non-volatile EEPROM memory chip from Microchip: 93LC66BT [datasheet](#) available from Microchip's website), which has 512 bytes/256 words (4kbits) available space. The memory can be accessed over a custom SPI protocol, using digital IO pins exposed in the DMM Shield connector: CS_EEPROM (EEPROM SPI chip select), DO (SPI MISO), DI (SPI MOSI) and CLK (SPI CLK).

While the chip select line is specific to EEPROM module, the SPI lines (data and clock) are shared with the DMM device.

Note the data is written and read from memory using word format addressing, instead of byte: bytes 0-1 are written at address 0x00, bytes 2-3 are written at address 0x01, etc.

The EEPROM is used to store the following system information:

Section Content	Addresses (words)	Size
Factory calibration data	0x93 – 0xFF	109 words / 218 bytes
Serial Number	0x8C – 0x92	7 words / 14 bytes
User calibration data	0x1F – 0x8B	109 words / 218 bytes
Free Memory	0x00 – 0x1E	31 words / 62 bytes

Please consult the DMM Shield Library User Guide for more information about the EEPROM module usage and communication. For more details about Calibration process, read more on [Calibration Procedure](#) below.

Measurement Scales

DMM Shield comes with preset scales of measurement. They will indicate the maximum value that can be accurately measured with the device. Keep in mind that at low values the resolution is lower and different scales might give a more accurate result since the device is calibrated closer that value. Ex: for a 40kΩ resistor is better to use the 50kΩ scale instead of the 500kΩ for a better resolution. There are 4 scales for voltages, 5 for current and 7 for resistances. Additionally, there are two extra scales for Diode and Continuity.

Scales	-	-	-	-	-	-	-	-
AC Voltage	50m	500m	5	30	-	-	-	V
DC Voltage	50m	500m	5	50	-	-	-	V
AC/DC Current	500u	5m	50m	500m	5	-	-	A
Resistances	50	500	5k	50k	500k	5M	50M	Ω
Diode								
Continuity								

The device comes factory calibrated for each scale. For more details about calibration please see the [Calibration procedure](#) below.

Accuracy

The accuracy of the DMM Shield is around 0.1% for AC/DC Currents and Voltages, 500Ω-5MΩ Resistances and within the scales; 1% for 50Ω and 50MΩ Resistances. **For AC Current and Voltage we guarantee the 0.1% accuracy at 50/60Hz.** Note that outrunning the end of a scale will increase the measurement error. The accuracy is computed in percentage as a difference between the reference value and the measured value, reported to full scale.

Let's consider $R_{\{F\}}$, $M_{\{F\}}$ as the reference and the measured value at full scale and $F_{\{S\}}$ the full scale. The accuracy is computed as follows:

$$Accuracy = \frac{R_{\{F\}} - M_{\{F\}}}{F_{\{S\}}} * 100\%$$

Calibration Procedure

The DMMShield needs calibration before performing measurements and delivering correctly measured values to the user. This is due to errors introduced by the chip itself and on-board additional electronics. Calibration is the process of computing and applying correction coefficients to the measured values that allow precise measurements.

The process consists of computing an additive and a multiplicative coefficient for each scale.

Calibration is done by collecting pairs of reference value and measured value (RefVal, MsVal) in multiple points. The reference value is the value measured with an accurate instrument, considered to be the actual value to be measured by the DMMShield device. The measured value is the value reported by DMMShield hardware. When all these pairs are collected, the calibration coefficients are computed mainly using the difference between the reference and the measured values.

Depending on the scale, different types of calibration are performed, as detailed in the following chapters:

2 Points Calibration for Resistance Scales

This method applies to the Resistance scales. It collects the pairs (RefVal, MsVal) in two points: 0 point (short between probes), and full scale value.

Let's consider this pairs as being $(R_{\{0\}}$, $M_{\{0\}})$ and $(R_{\{F\}}$, $M_{\{F\}})$. The calibration coefficients are computed in the following manner:

$$Calib_{\{ADD\}} = (R_{\{0\}} - M_{\{0\}}) / (1 + \frac{R_{\{F\}} - M_{\{F\}}}{F_{\{S\}}})$$

$$\text{Calib_MULT} \cdot \text{label}_2 = 0$$

The reference value for the short is considered to be 0: $R_0 = 0$

The calibration coefficients are applied to the acquired value in the following manner:
$$\text{Value_corrected} = (1 + \text{Calib_MULT}) \cdot \text{Value_acquired} + \text{Calib_ADD} \cdot \text{label}_3$$

3 Points Calibration for DC

This method applies to the DC Voltage and DC Current scales. It collects the pairs (RefVal, MsVal) in three points: 0 point (short between probes for voltage and open for current), negative full scale value and positive full scale value. For example, for VoltageDC500m scale, the following points are used: 0 point (short between probes), -500mV, 500 mV.

Let's consider this pairs as being (R_0, M_0) , (R_{FN}, M_{FN}) and (R_{FP}, M_{FP}) . The calibration coefficients are computed in the following manner:

$$\text{Calib_MULT} = \frac{R_{FP} - R_{FN}}{M_{FP} - M_{FN}} - 1$$
$$\text{Calib_ADD} = (R_0 - M_0)(1 + \text{Calib_MULT})$$

The reference value for the zero calibration is considered to be 0: $R_0 = 0$

The calibration coefficients are applied to the acquired value in the following manner:
$$\text{Value_corrected} = (1 + \text{Calib_MULT}) \cdot \text{Value_acquired} + \text{Calib_ADD} \cdot \text{label}_6$$

2 Points Calibration for AC

This method applies to the AC Voltage and AC Current scales. It collects the pairs (RefVal, MsVal) in two points: 0 point (short between probes for voltage and open for current) and full scale value. For example, for VoltageAC500m scale, the following points are used: 0 point (short between probes) and 500 mV.

Let's consider this pairs as being (R_0, M_0) , (R_F, M_F) . The calibration coefficients are computed in the following manner:

$$\text{Calib_MULT} = \frac{R_F}{\sqrt{M_F^2 - M_0^2}} - 1$$
$$\text{Calib_ADD} = M_0 \cdot \text{label}_8$$

The reference value for the zero calibration is considered to be 0: $R_0 = 0$

The calibration coefficients are applied to the acquired value in the following manner:
$$\text{Value_corrected} = (1 + \text{Calib_MULT}) \cdot \sqrt{\text{Value_acquired}^2 - \text{Calib_ADD}^2} \cdot \text{label}_9$$

Software Libraries

Digilent provides libraries to access DMM Shield functionality. The libraries were created to support ZYNQ platform and Digilent PIC32 microcontroller boards. Both libraries come with a demo that allows the communication with the DMM Shield through UART. Functions as setting a scale and measure can be accessed by entering commands in the UART terminal emulator. Another demo shows how to access the memory left in the [EEPROM](#) by reading and writing 32 words. Documentation and downloads for these libraries can be found at the following locations:

- [ZYNQ](#)
- [PIC32](#)
- [Arduino](#)

Appendix: Pinout Tables

DMM Shield Connector Pinout

Banana Connector Interface

J1	J2	J3	J4
Voltage/ Ω	COM	Current (mA)	Current (A)

Power Connector

J9	
Connector pin number	Arduino Shield Name
1	<u>NC</u>
2	3V3
3	<u>NC</u>
4	3V3
5	5V0
6	<u>GND</u>
7	<u>GND</u>
8	VIN

Analog Connector

J6			
Outer Row		Inner Row	
Connector pin number	Arduino Shield Name	Connector pin number	Arduino Shield Name
1	A0	2	A6
3	A1	4	A7
5	A2	6	A8
7	A3	8	A9
9	A4	10	A10
11	A5	12	A11

Digital IO Connector

J7			
Inner Row		Outer row	
Connector pin number	Arduino Shield Name	Connector pin number	Arduino Shield Name
1	IO41	2	A
3	IO40	4	G
5	IO39	6	IO13/CLK
7	IO38	8	IO12/DI
9	IO37	10	IO11/DO
11	IO36	12	IO10/CS_DMM
13	IO35	14	IO9/CS_EEPROM
15	IO34	16	IO8

J8			
Inner Row		Outer Row	
Connector pin number	Arduino Shield Name	Connector pin number	Arduino Shield Name
1	IO33	2	IO7
3	IO32	4	IO6
5	IO31	6	IO5
7	IO30	8	IO4/RLD
9	IO29	10	IO3/RLU
11	IO28	12	IO2/RLI
13	IO27	14	IO1
15	IO26	16	IO0

About this Document

This reference manual applies to Revision C of the DMM Shield.

Additional Information

- [Arduino DMM Shield Library User Guide](#)
- [Arty Z7 DMM Shield Oled Demo User Guide](#)
- [Arty Z7-20 DMM Shield Webserver Demo User Guide](#)
- [PIC32 DMM Shield Library User Guide](#)
- [Zynq DMM Shield Library User Guide](#)

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