MP406 Moisture Probe Operation Manual

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1. Introduction

The MP406 Moisture Probe can be used to measure the moisture content in many materials such as soil, food and materials used in roadway and building construction.

The MP406 can be used to measure the soil moisture for scientific research or irrigation management. In either situation the MP406 can:
- rapidly measure the soil moisture by pushing the needles of the sensor into the soil surface or soil profile;
- make measurements over time by permanently burying the MP406 and connecting it to a data logger;
- control irrigation by permanently burying the MP406 and connecting it into an irrigation controller.

2. Operation

2.1 Hand Held Moisture Probe Meter

The MP406 has a connector which plugs directly into the MPM-160 hand held meter for direct readout.

The meter provides the power to the MP406 for the reading, display and storage of measurements. The returned mV signal is displayed directly as mV and is also converted and displayed as Volumetric Water Content (VSW%). Refer to section 2.4.4 for the conversion table.

When being used with a hand held meter the MP406 is usually connected to a set of chrome extension rods which have a T handle on the end.

The extension rods enable the operator to insert the needles of the MP406 into the soil surface without bending over and then for him to more conveniently read the MPM-160 meter.

2.2 Data Logging or Irrigation Control

2.2.1 General

The MP406 exterior is made from extremely durable ABS plastic formed into a custom designed tube. The electronics is totally sealed within this tube. The needles are made from high quality stainless steel. Then the MP406 can be buried permanently at a location as part of either an input to a data logging system or for an input to an irrigation controller or environmental monitoring system.

2.2.2 Installation

The MP406 can be installed by drilling a close fitting hole into the soil profile, either at an angle or vertically or it can be installed horizontally from a larger augered hole or soil pit. In all situations care must be taken to ensure the needles are in contact with soil profile after installation. It is usual practice to install the MP406 with the 3 needles in a horizontal plane in order to maximise the measurement of soil spatial variability. The MPM-160 meter should be used during the installation process to ensure good contact of the needles and the soil is maintained during back filling of the hole.

2.2.3 Cable Length

The standard cable length is 4.5 m. This may be extended by using suitable cable.

Multi Core Polypropylene Insulated Irrigation Control Cable, specifications 9 core (9 x 7/0.30) has been tested successfully over 500 m. Two wires were connected for power supply positive from the data logger to the MP406.

2.2.4 Power

The MP406 is normally powered by a voltage in the range 7.0 to 18.0 volts using 18 mA of power. It can function satisfactorily within the voltage limits of 7.0 to 18.0 volts provided 18 mA is maintained.

1 x MP406 = 32 mA (maximum power use)

5 seconds of warmup/hour = 5/3600 x 32 = 0.04 mAh

Total of 16 x MP406 = 16 x 0.04 mAh = 0.64 mAh

Logging for 24 hours on an hourly frequency = 0.64 x 24 = 15.36 mAh/day

Gel Cell Battery 7 Ah capacity. Then = 7/0.01536 = 455 days

In other words a Gel Cell battery is capable of supplying enough power for about 455 days. The battery would need to be recharged within about 30 days as it will self discharge in this time.

2.3 Theory of Operation

2.3.1 Theory

The MP406 has a high frequency moisture detector which uses the standing wave principle to indicate the ratio of two or more substances forming a body of material, each substance having a different electric constant (Ka).

The moisture measurement of the material is based upon the fact that in a water: soil: air matrix, the dielectric constant is dominated by the amount of water present. The dielectric constant of water is approximately equal to 80 whereas the dielectric constant of soil is approximately equal to 3 or 4 and air is equal to 1. Therefore any changes in the volume matrix ratio of water will result in a substantial change in the dielectric constant of the matrix. Then the soil water content can be measured exactly because changes in water content of the soil result in changes in the dielectric constant of the soil.

The material that can be measured by the MP406 is often soil but can be any composition of non-metallic powdered, liquid or solid phase substance into which the needles are inserted.

2.3.2 Results

The results from measurement of absolute volumetric soil water percent (VSW%) from prepared soil samples using the MP406 are given in Figure 1. This result is typical of the results obtained from comparative testing of the MP406 in prepared soil samples, for a wide range of agricultural soils.

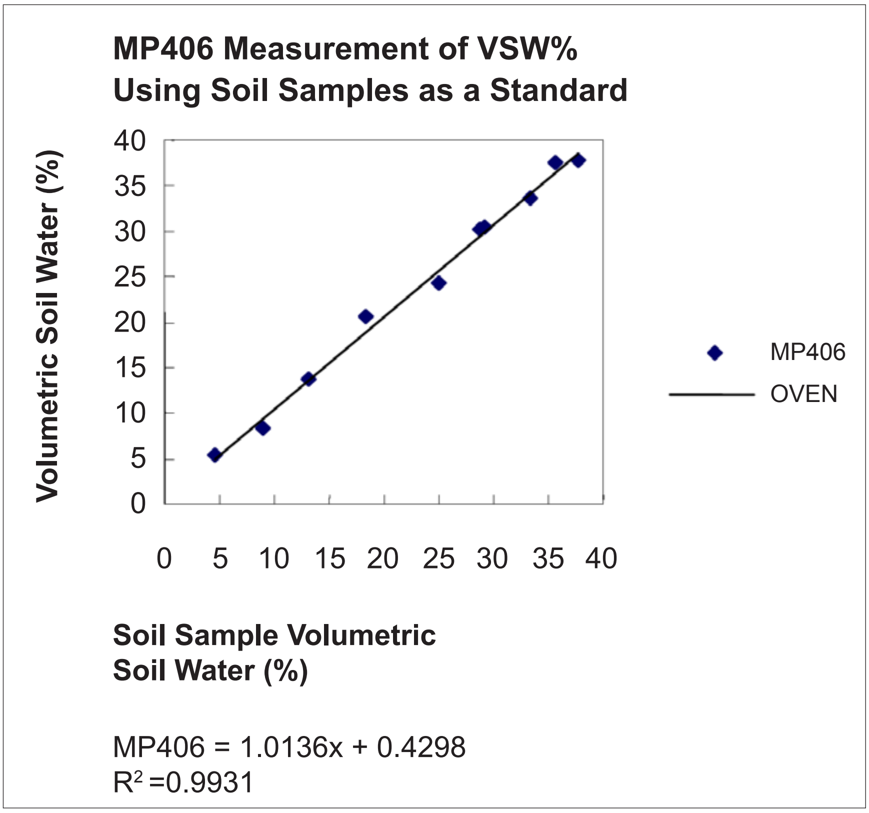


Figure 1. MP406 Measurement of Absolute Volumetric Soil Water Percent from Prepared Soil Samples as a Standard.

The results from measurement of the absolute volumetric soil water percent (VSW%) using the MP406 when compared with TDR technology are given in Figure 2. This result is typical of the results obtained from comparative testing of the MP406 compared to TDR technology for a wide range of agricultural soils.

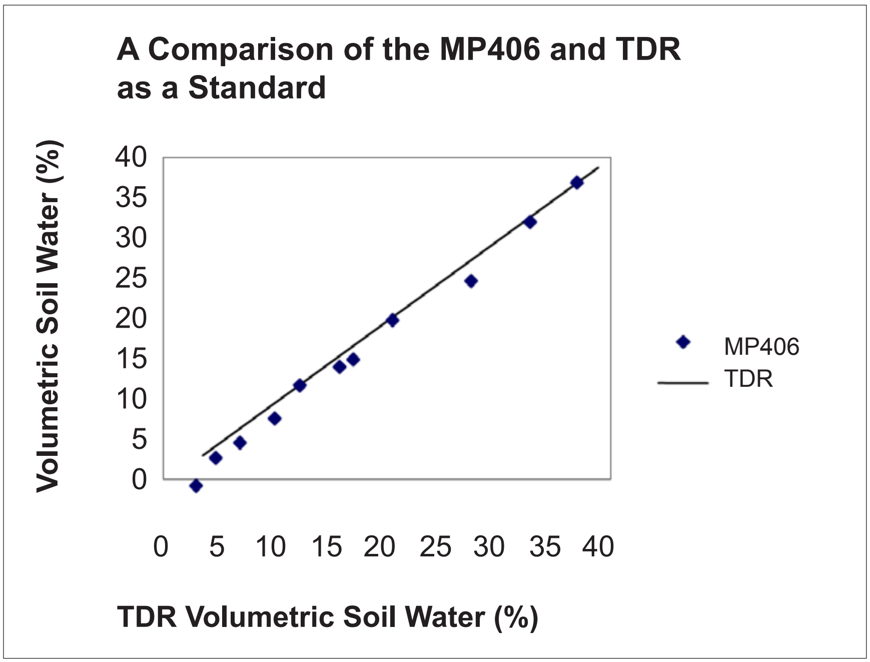


Figure 2. The MP406 in comparison to TDR Measurement of Absolute Volumetric Soil Water Percent as a Standard.

2.3.3 Definitions

Gravimetric Soil Water Content is defined as

$$\theta_G = \frac{Mw}{Ms}$$

Where Mw is the mass of water in the soil sample and Ms is the total mass of the dry soil sample.

Volumetric Soil Moisture Content is defined as

$$\theta_V = \theta_G * Ps$$

Where Ps is the bulk density of the soil sample $\left(= \frac{Ms}{Vs} \right)$

Where Ms is the total mass of the dry sample and Vs is the total volume of the dry soil sample.

Volumetric Soil Water Percent (VSW%)

$$VSW\% = \theta v * 100$$

The VSW% typically varies in the field from 2–5% for sandy soils at permanent wilting point to 45–55% for clay soils at saturation.

2.4.4 Polynomial Lookup Table

Linearisation tables can be added to Data Loggers using the following data:

A: Conversion Table for MP-406 - From VSW% to mV & mA in mineral soil.

VSW%	mV MP-406	mA MP-406	VSW%	mV MP-406	mA MP-406
-5.0	0.0	4.00	55.00	1015	18.50
2.00	120	5.71	60.00	1025	18.64
5.00	210	6.99	65.00	1035	**18.785**
10.00	310	8.43	70.00	1045	18.93
15.00	415	9.93	75.00	1055	19.07
20.00	510	11.285	80.00	1065	19.21
25.00	610	12.71	85.00	1070	19.28
30.00	720	14.285	90.00	1080	19.43
35.00	825	15.785	95.00	1095	19.64
40.00	895	16.785	100.00	1120	20.00
45.00	955	17.64	105.00	2090	
50.00	1005	18.35			

B: Polynomial Lookup Table for Organic and Mineral Soil

Soil moisture θ_v, $m^3.m^{-3}$	mV, organic soil	mV, mineral soil	soil moisture θ_v, $m^3.m^{-3}$	mV, organic soil	mV, mineral soil
-0.0	-209	-209	0.55	985	1015
0	50	120	0.6	1010	1025
0.05	140	210	0.65	1020	1035
0.1	230	310	0.7	1030	1045
0.15	320	415	0.75	1045	1055
0.2	415	510	0.8	1055	1065
0.25	500	610	0.85	1070	1070
0.3	600	720	0.9	1080	1080
0.35	700	825	0.95	1095	1095
0.4	800	895	1.0	1106	1106
0.45	875	955	1.05	2090	2090
0.5	940	1005			

2.5 Wiring

The MP406 is supplied with 4.5 m of four core shielded wire.

Wiring

Red = 7-16V dc

Blue and shield = Analogue Ground (Signal Return)

Yellow = signal +

Black = DC Ground

MP406 & MP306 Soil Moisture Sensor

The MP406 and MP306 sensor has a high frequency moisture detector which uses the standing wave principle to indicate the ratio of two or more substances forming the body of a material, each substance having dielectric constant (Ka).

Water (Ka)	= 80
Clay (Ka)	= 3
Sand (Ka)	= 2
Air (Ka)	= 1

The moisture measurement of the material is based upon the fact that in a water, soil, air matrix, the dielectric constant is dominated by the amount of water present. Soil water content can be measured exactly as changes in the water content of the soil result in changes in the dielectric constant of the soil.

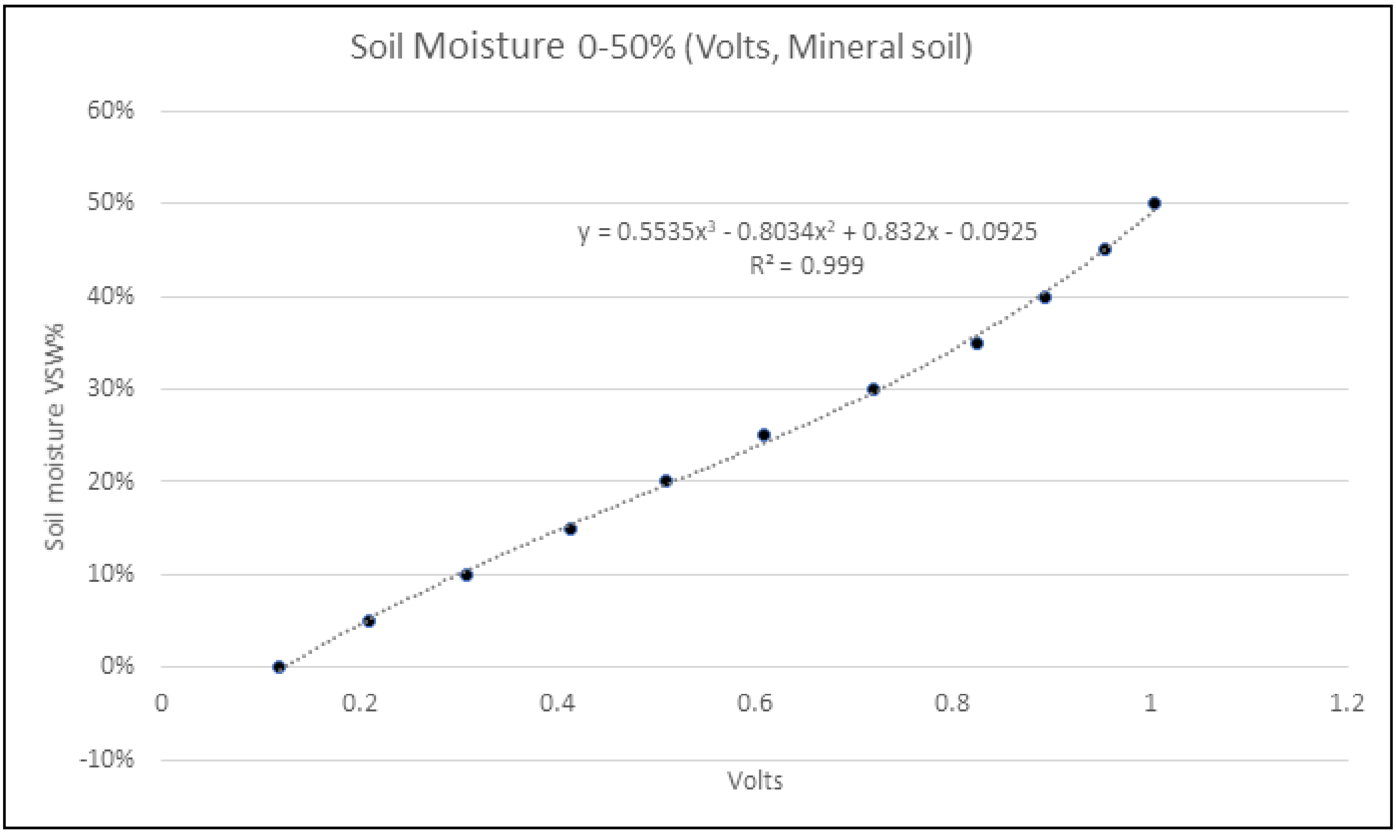
Materials that can be measured by the MP406/MP306 sensor are most often soil, but can also be any composition of non-metallic powdered, liquid or solid phase substance into which the needles are inserted.

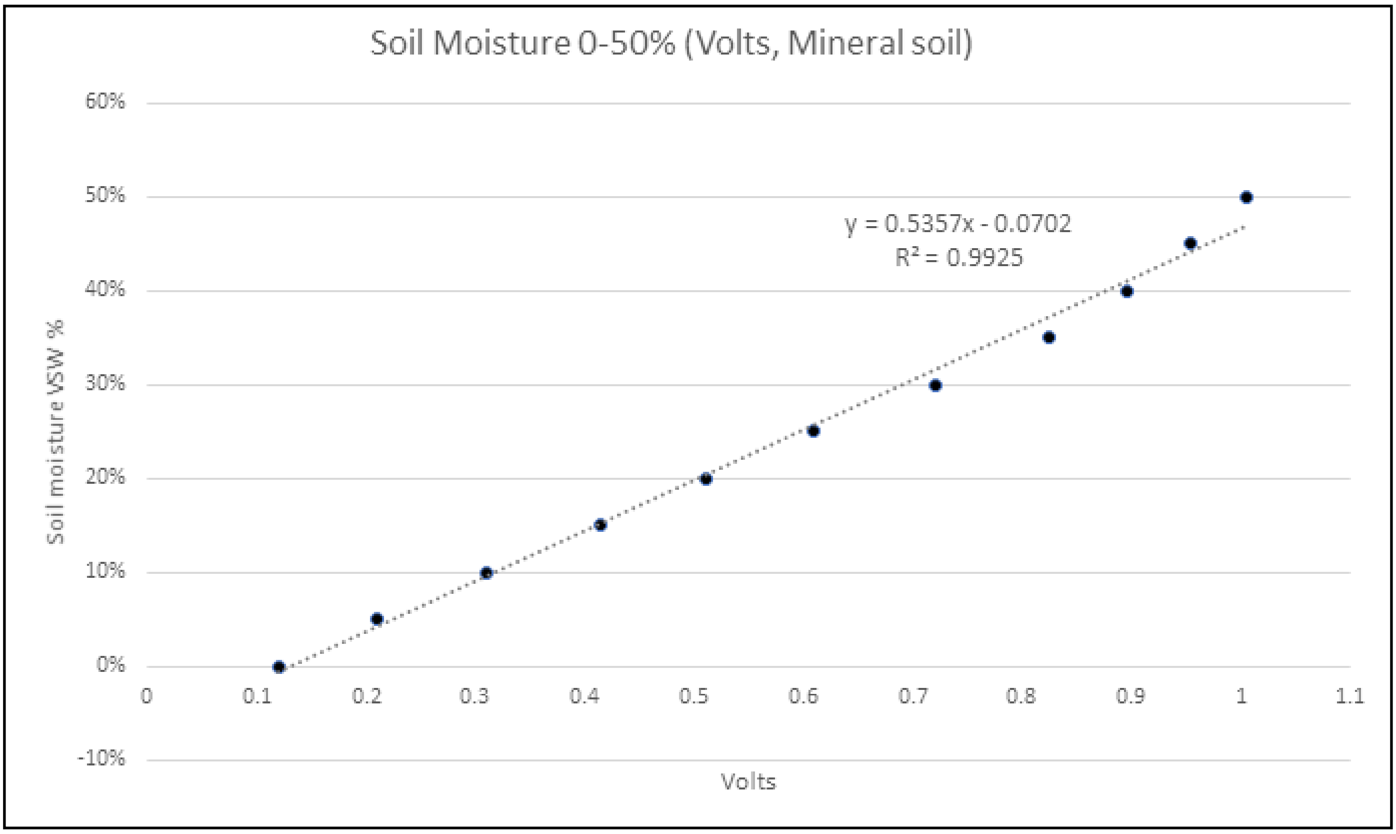
Results

The results from measurement of absolute volumetric soil water percent (VSW%) from prepared soil samples using the MPKit are given in Figure 1. This result is typical of the results obtained from comparative testing of the MPKit in prepared soil samples, for a wide range of agricultural soils.

The results from measurement of the absolute volumetric soil water percent (VSW%) using the MPKit when compared with Trase® TDR technology (Soil Moisture Equipment Corp.) are given in Figure 2. This result is typical of the results obtained from comparative testing of the MPKit compared to Trase® TDR technology for a wide range of agricultural soils.

Moisture Probe Equations & Polynomial Lookup Table





The formulas to derive these equations are available as both Microsoft Excel files and as an R Script on request.

Moisture Probe Sensor Calibration

The results obtained from measurement of the absolute volumetric soil water percent (VSW%) using the MPKit are expected to be within ± 2-5% of the actual soil moisture as determined in the laboratory by gravimetric and volumetric methods of determination.

Recalibration is not expected to be necessary for most applications in most commonly occurring agricultural soils. This is especially so when it is considered that for practical end uses such as irrigation scheduling and irrigation control the **change** in VSW% is the most important variable to be determined for management decision making. The **change** measured will be correct in absolute VSW% units or mm of water applied as the relationship of voltage output to water content, hence calibration slope remains constant, across all soil types.

Scientists or regulatory authorities may wish to calibrate the MPKit to verify the data measured. In this case, it is simply necessary to compare the MPKit output in mV to the VSW% from the soil samples, either prepared in the laboratory or obtained in the field. The resultant regression of these variables will provide the new calibration of the MPKit. All MP306/MP406 are manufactured to be identical. All MPKit respond to changes in water content of the soil and the resultant changes in the dielectric constant in the same way and hence the same calibration will apply to all MPKits.

Equations for Programming IoT Nodes that Use MP406

The formulas to derive these equations are available as both Microsoft Excel files and as an R Script on request.

Linear Calibration

VSW% 0~50	= a + b χ
	= INTERCEPT + SLOPE
	= -0.5357 + 0.0702
	R^2 =0.9925

Where χ = MP Sensor output in volts

{Output Range of Sensor $0 \leq$ Sensor ≤ 1200 mV
{Limits of VSW% $0\% \leq$ VSW% $\leq 50\%$

Polynomial Calibration

VSW% 0~50	$= a_o + a1\chi + a2\chi^2 + a3\chi^3$
	$= -0.0925 + 0.8319\chi - 0.8034\chi^2 + 0.5535\chi^3$
	R^2 Value =0.9990

Where χ = MP Sensor output in volts

{Output Range of Sensor $0 \leq$ Sensor ≤ 1.20 V
{Limits of VSW% $0\% \leq$ VSW% $\leq 50\%$

Definitions

Gravimetric Soil Water Content

$\Theta_G = \frac{Mw}{Ms}$ Where Mw is the mass of water in the soil sample and Ms is the total mass of the dry soil sample.

Volumetric Soil Moisture Content

$\Theta_G = \Theta_G * \rho b$ Where ρb is the bulk density of the soil sample

$(= \frac{Ms}{Vs})$ Where Ms is the total mass of dry sample and Vs is the total volume of the dry soil sample

Volumetric Soil Water Percent (VSW%): VSW% = Θv * 100

The VSW% typically varies in the field from 2-5% for sandy soils at permanent wilting point to 45-55% for clay soils at saturation.

Polynomial Lookup Table

Soil Moisture (%)	mV, mineral soil	Volts
0	120	0.120
5	*210*	*0.210*
10	310	0.310
15	*415*	*0.410*
20	510	0.510
25	*610*	*0.610*
30	720	0.720
35	*825*	*0.825*
40	895	0.895
45	*955*	*0.955*
50	1005	1.005
55	*1015*	*1.015*
60	1025	1.025
65	*1035*	*1.035*
70	1045	1.045
75	*1055*	*1.055*
80	1065	1.065
85	*1070*	*1.070*
90	1080	1.080
95	*1095*	*1.095*
100	1106	1.106

2.6 Technical Specifications

2.6.1 Mechanical Diagram

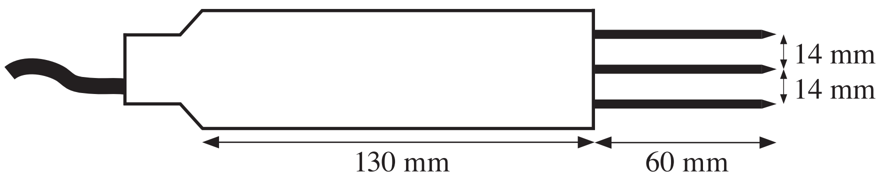


Figure 3. Mechanical Dimensions

2.6.2 Electrical and Mechanical Specifications

Measurement Range	0–100 VSW%
Accuracy	+/-1 VSW%
Interface	Input requirements: 7–18 V DC unregulated Power consumption: 32 mA typical Output signal: 0–1 V for 0–50 VSW%
Response Time	Less than 0.5 seconds
Stabilization Time	5 seconds approximately from power-up
Mechanical	Total length 215 mm. Diameter 40 mm Needle length 60 mm, needle separation 14 mm Exterior ABS Plastic Needles Stainless Steel Cable 4.5 m Standard
Environment	Designed for permanent burial

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