

Specification for the CCDPS DAQ/Control  
Capacitor Charge/Discharge Power Supply (CCDPS) for FLARE

March 8, 2016

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# 1 Specifications for DAQ/control

## 1.1 Description

The data acquisition (DAQ) and control system for the FLARE CCDPS controls all charging and dumping of the capacitors, monitors charge voltages, temperatures and discharge current. The DAQ is shown in the wiring schematic in Fig. 1.

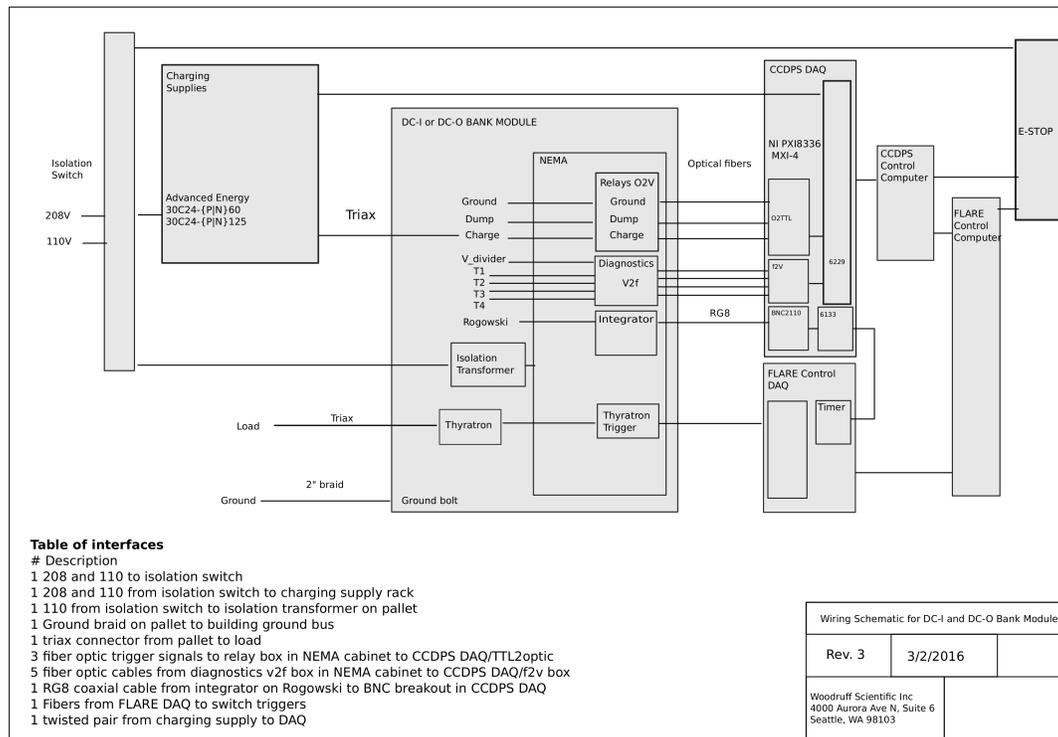


Figure 1: Connections

The connection schematic in Fig. 1 shows all of the connections that need to be made to the bank modules, power and control systems. From the left of Fig. 1, 208 and 110 power is fed to the bank enclosures via a Kirk key controlled isolation switch. This same switch can be energized by an Emergency Stop (E-stop) button located in the control room (this E-stop is digitized by both the FLARE control DAQ and the CCDPS control DAQ). If energized, the switch will drop all power to the enclosure, thereby killing power to the HV dump (normally closed) and charge (normally open) relays, and dumping bank energy into the cap dumps. The 110 and 208 power is delivered to the charging supply rack (located on it's own separate pallet), and 110 is also delivered to an isolation transformer mounted on the bank module pallet. Connections to the load are made by multiple triax cables (described above). Water is connected to the ignitron switches along 1/4" tubes from a shared chiller unit. The charge, dump ground relays are controlled by individual fiber-optic-enabled switches, with pulse signals sent from the CCDPS DAQ rack. Temperature sensor data are transmitted by fiber-optics from the pallet to the DAQ after conversion of voltage to frequency, then reconverting at the DAQ. A BNC connection is made from the current sensor integrator to the DAQ fast data acquisition (sampling at at least 1MHz). Timing synchronization is provided by the FLARE control DAQ. Switch firing is controlled here by the FLARE control computer and DAQ, by transmission of fire signal by fiber-optic connection. CCDPS DAQ requires 110V as input, separately from any power to the banks. This will allow the bank charge to be monitored on the CCDPS control even in the event of ESTOP. CCDPS control computer requires 110V as input.

Signal	OH	EF	GF	PF	TF	DC	Total
TTL to Fiber	3	3	9	6	6	6	33
$V_{Bank}$	1	1	1	1	1	1	6
$V_{Charger}$	1	1	1	1	1	1	6
$T_{Bus}$	1	1	3	2	2	0	9
$T_{Dump}$	1	1	3	1	1	2	9
$T_{Water}$	1	1	3	1	1	2	9
$T_{Anode}$	1	0	3	4	2	0	10
ESTOP	0	0	0	0	0	0	1
$I_{Rogowski}$	1	1	3	2	2	2	11

Table 1: Signals coming to/from DAQ - 33 TTL's, 50 slow AI's, 11 fast AI's

## 1.2 Full Assembly: DAQ

Fig. 2 shows an example of a full DAQ assembly mounted on one 36 inch square steel pallet, consisting of rack cabinet (shielded for noise), NI chassis, NI cards, BNC break-outs and TTL-fiber outputs. The appendix contains a breakout of the NI system that we could use along with information about the main cards (two fast AI cards (6133), two slow AI and DO cards (6229), chassis, BNC input boards, and a timing card for synchronization to the FLARE main control DAQ (6651)).



Figure 2: Example DAQ full assembly

LabVIEW software will communicate with FLARE control software and will handle the following:

1. Charge on/off
2. Bank voltage
3. Dump
4. Acquisition of shot data from Rogowski
5. Transfer of shot data to FLARE control
6. Go/No-Go signal based on signal from FLARE control computer

### 1.3 Diagnostics

A current sensor will be needed to measure the current at the forward switch, with suitable clamp arrangement (see Fig. 3 for example of PEM CWT B and clamp). Circuits will be needed to convert a voltage measurement (representing temperature or bank charge) to an optical signal such as those shown in Fig. 4, and back to voltage again at the DAQ. Analog panel meters will be needed in addition to digitizing the charge voltage for the DAQ/control, which will be mounted on the bank for visual inspection prior to safing. An example is shown in Fig. 5. Please refer to the BOM for detailed break-out of components.



Figure 3: Example current sensor and mounting clamp.

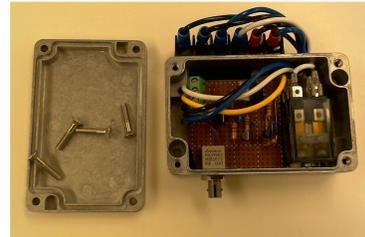
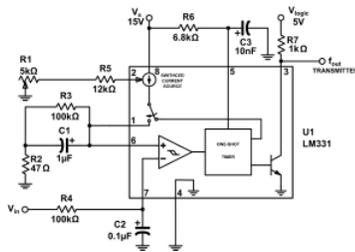


Figure 4: Example voltage to frequency converter circuit

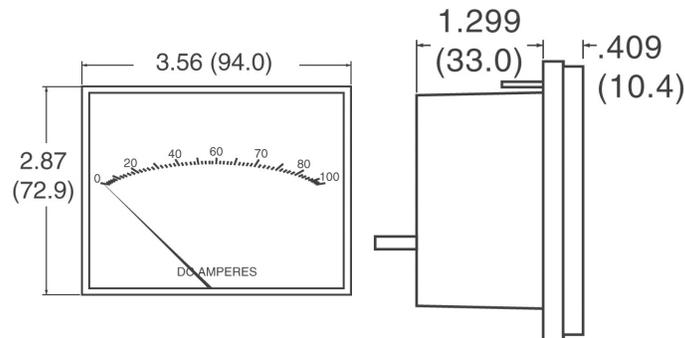


Figure 5: Example panel mount analog meter.

## 2 References

### References

- [1] Statement of Work for Design of Capacitor Charge/Discharge Power Supply (CCDPS) for FLARE FLARE-CCDPS-150828, Revision 0, Sept. 9th 2015

## 3 Appendices

### 3.1 Labview control software

#### 3.1.1 LabVIEW Program Outline

This is a basic description of how the existing LabVIEW Virtual Instrument (VI) is organized. Changes to the program need to be made before it is appropriate for CCDPS use.

The user sees a control panel with appropriate controls: Bank voltages, bank enable/disable, DAQ channel assignments, bank firing timings, and other controls are available.

The user starts the experiment by clicking 'Fire Experiment'. Abort buttons are available in every view, which stops the experiment immediately.

The VI block diagram contains the LabVIEW code and is divided into three structures: 1) Program Initialization; 2) Event Structure; and 3) Case Structure.

Two clusters are used to pass information throughout the VI. The experiment state cluster contains bank and DAQ system parameters and is passed throughout the VI. The experiment control cluster is also passed throughout the VI; it tells the case structure when to start and which stage of the shot it is currently in.

#### 3.1.2 Program Initialization

- Runs once after starting the VI
- Sets up experiment state cluster
- Sets up voltage monitoring of banks

#### 3.1.3 Event Structure

- Monitors changes to the front panel initiated by user
- Possible changes include: changing bank voltages, disabling banks, etc.
- Also watches for 'Fire Experiment' or 'Abort' buttons to be clicked
- Applies the appropriate changes to the Experiment State Cluster

#### 3.1.4 Case Structure

- Controls the procedure during a shot
- Waits for user to 'Fire Experiment', then runs the shot
- Initializes DAQ cards
- Charges banks and holds until all banks are charged
- Fires the shot

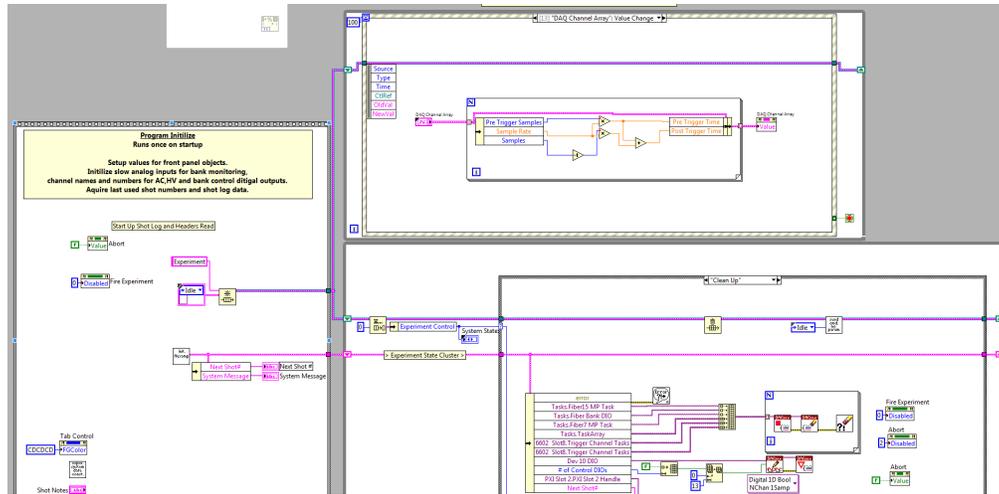


Figure 6: Existing LabVIEW control software showing three structures.

- Acquires, displays, and saves data
- Stops the DAQ cards and the VI

The LabVIEW VI is designed to be extensible. Additional banks or DAQ channels can be added in a straightforward manner. Additional controls are also able to be added.

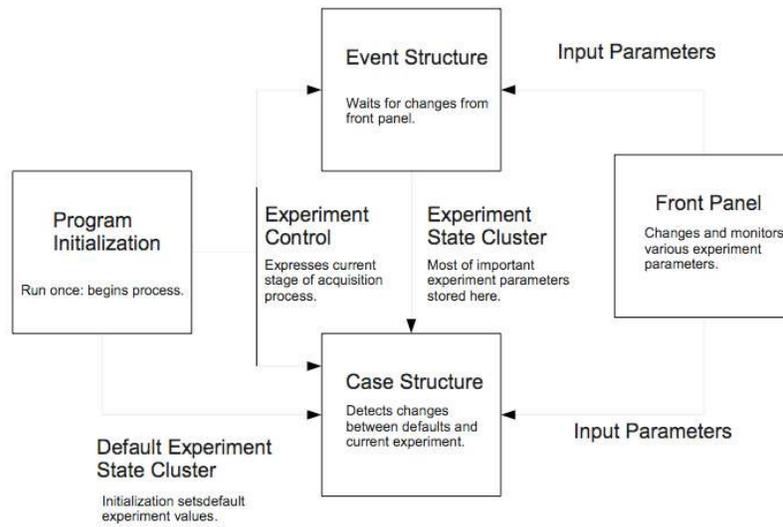


Figure 7: Code Structure of existing LabVIEW control software

### 3.2 Example NI system for DAQ


[Print this Page](#) | [Close Window](#)
**Configuration ID and Retrieval Information**
Configuration ID: **PX4916726**Retrieve configuration at: [www.ni.com/advisor/retrieve/](http://www.ni.com/advisor/retrieve/)

\* Please refer to this ID when speaking with a Sales Representative

**Contact Information**

11500 N Mopac Expwy Austin, TX 78759-3504

Tel: (800) 531-5066 Fax: 512-683-8411

**Purchase Options**
Online: [www.ni.com/advisor/retrieve/](http://www.ni.com/advisor/retrieve/)

Fax: 512-683-8411 (Include Purchasing Information)

**PXI Advisor -Summary**
**Total Price: \$ 28,246.61**
**You Save: \$ 622.87 (2%)**
**Controller**

Part Number	Model	Description	Quantity	Price Per Unit
781039-01	NI PXIe-PCIe8375, 10m Cable	NI PXIe-PCIe8375 x4 MXI-Express Kit with Fiber Optic Cable, 10 m	1	\$ 3,949
		Standard Repair Coverage	1	
				<b>Subtotal: \$ 3,949</b>

**Modules**

Part Number	Model	Description	Quantity	Price Per Unit
778771-01	NI PXI-6133/16 MSamples	NI PXI-6133 16 MS Memory S Series Multifunction DAQ Module	2	\$ 3,086
		Standard Repair and Traceable Calibration Coverage	2	
779554-01	TB-2709	TB-2709 PXI Front-Mount SMB Terminal Blk for PXI-6123 & PXI-6133	2	\$ 234
		Standard Repair Coverage	2	
763389-01	SMB-100, SMB Female to BNC Female Coax Cable, 50 Ohms, 0.6m, Qty 1	SMB-100, SMB to BNC Female	2	\$ 68
779630-01	NI PXI-6229	NI PXI-6229 (32 Analog Inputs, 48 Digital I/O, 4 Analog Outputs)	2	\$ 1,173
		Standard Repair and Traceable Calibration Coverage	2	
782536-01	SCB-68A	SCB-68A Noise Rejecting, Shielded I/O Connector Block	2	\$ 330
		Standard Repair Coverage	2	
782536-01	SCB-68A	SCB-68A Noise Rejecting, Shielded I/O Connector Block	2	\$ 330
		Standard Repair Coverage	2	
192061-02	SHC68-68-EPM Cable (2m)	SHC68-68-EPM Shielded Cable, 68-D-Type to 68 VHDCI Offset, 2 m	2	\$ 143

192061-02	SHC68-68-EPM Cable (2m)	SHC68-68-EPM Shielded Cable, 68-D-Type to 68 VHDCI Offset, 2 m	2	\$ 143
782110-01	NI PXI-6683H	NI PXI-6683H GPS,IRIG-B, IEEE 1588 Sync and Time Module with TCXO	1	\$ 2,199
		Standard Repair Coverage	1	
188858-01	SMB 210 Cable, Dual SMB Plug to Dual SMB Plug Coax, 50 Ohm (1m)	SMB 210 Cable, Dual SMB Plug to Dual SMB Plug Coax, 50 Ohm, 1M	1	\$ 112

**Subtotal: \$ 13,325****Chassis**

Part Number	Model	Description	Quantity	Price Per Unit
781622-01	NI PXIe-1078	NI PXIe-1078, 9-Slot 3U PXI Express Chassis	1	\$ 2,435
		Standard Repair Coverage	1	
763000-01	United States 120VAC	Power Cord, AC, U.S., 120 VAC, 2.3 meters	1	\$ 9

**Subtotal: \$ 2,444****Services**

Part Number	Model	Description	Quantity	Price Per Unit
SRV-PX4916726	Standard Services	Standard Service Program for PXI Systems	1	\$ 4,152.48 <b>\$ 3,529.61</b>

**Subtotal: \$ 3,529.61****You Save: \$ 622.87 (15%)****Software**

Part Number	Model	Description	Quantity	Price Per Unit
776678-35	NI LabVIEW Professional Development System for Windows	LabVIEW Professional Development System, Windows, English, Include 1 Year SSP	1	\$ 4,999

**Subtotal: \$ 4,999****Total Price: \$ 28,246.61****You Save: \$ 622.87 (2%)**

\* Price does not include local taxes or delivery charges.

Configuration ID: [PX4916726](#) Retrieve configuration at: [www.ni.com/advisor/retrieve/](http://www.ni.com/advisor/retrieve/)

The **CWT** from *Power Electronic Measurements Ltd.* is a state of the art wide-bandwidth ac current probe.

The CWT is ideal for power electronics development work because it combines an easy to use thin, flexible, clip-around coil with an ability to accurately replicate fast switching current waveforms be they sinusoidal, quasi-sinusoidal or pulsed.



A 2700A current pulse with a 6700A/µs falling edge measured by a CWT15 with a 500mm coil and a very high bandwidth coaxial shunt - 10µs/div.

## Applications

- Monitoring current waveforms for semiconductor switches
- Development and servicing of power electronic equipment
- Monitoring high frequency sinusoidal currents
- Measuring fault currents or circuit breaker interruption currents
- Measuring pulses of current
- Measuring ac currents superimposed on large dc currents
- Measuring harmonic current components
- Measuring signal or earth leakage currents in 3-phase supply systems

## Features

- Measurement range from **300mA to 300,000A**
- Typical bandwidths from **0.1Hz to 16MHz**
- The DC offset is no greater than 2mV over the operating temperature range.
- **Thin and flexible, 'clip-around' coil** in lengths from **300mm to 1000mm** – other lengths available as custom designs
  - ⇒ Easy to insert probe in confined spaces
  - ⇒ Robust lockable 'clip-in' mechanism
  - ⇒ Non-intrusive – loading the circuit under test by only a few pH
- Coil peak voltage isolation capability up to 10kV
- Instantaneous  $\pm 6V$  peak to peak output to plug directly into scope, data acquisition equipment, DVM or power recorders
- CE Marked
- Accuracy of  $\pm 1\%$  of reading

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Nottingham, U.K.

Tel: + 44 (0) 115 925 4212 Fax: + 44 (0) 115 967 7685

Email: info@pemuk.com Website: www.pemuk.com

## PERFORMANCE CHARACTERISTICS

Type	Sensitivity (mV/A)	Peak current (kA)	Peak di/dt (kA/μs)	Noise max <sup>1</sup> (mV <sub>pk-pk</sub> )	Droop typ. (%/ms)	LF (3dB) bandwidth typ. (Hz) $f_L$	Phase lead at 50Hz typ. (deg)	HF (3dB) bandwidth typ. (MHz) $f_H$ <sup>2</sup>	
								Coil Length 300mm	Coil Length 700mm

### High Sensitivity Ranges of CWT ... measuring currents from 300mA

CWT015	200.0	0.03	0.2	6.5	130	150	2.0 @ 6kHz	6	4
CWT03	100.0	0.06	0.4	4.5	90	105	2.0 @ 4kHz	10	6.5
CWT06	50.0	0.12	0.8	3.0	70	80	2.0 @ 3kHz	16	10
CWT1	20.0	0.3	2.0	2.5	40	50	1.9 @ 2kHz	16	10
CWT1N	20.0	0.3	2.0	2.0	20	25	1.9 @ 1kHz	10	5
CWT3	10.0	0.6	4.0	8.0	3.0	3.5	1.0 @ 300Hz	16	10

### Standard Ranges of CWT ... measuring currents from 15A

CWT3N	10.0	0.6	4.0	14.0	0.9	1.0	1.7	10	5
CWT6	5.0	1.2	8.0	14.0	0.9	1.0	1.7	16	10
CWT15	2.0	3.0	20.0	7.0	0.7	0.8	1.3	16	10
CWT30	1.0	6.0	40.0	5.0	0.5	0.6	0.9	16	10
CWT60	0.5	12.0	40.0	3.5	0.35	0.4	0.6	16	10
CWT150	0.2	30.0	40.0	3.0	0.2	0.2	0.3	16	10
CWT300	0.1	60.0	40.0	3.0	0.1	0.1	0.2	16	10
CWT600	0.05	120.0	40.0	3.0	0.06	0.05	0.1	16	10
CWT1500	0.02	300.0	40.0	3.0	0.035	0.03	0.06	16	10

<sup>1</sup>. Distributed around the  $f_L$  (-3dB) bandwidth.

<sup>2</sup>. For 2.5m cable length. Contact PEM for values of  $f_H$  for other coil and cable lengths

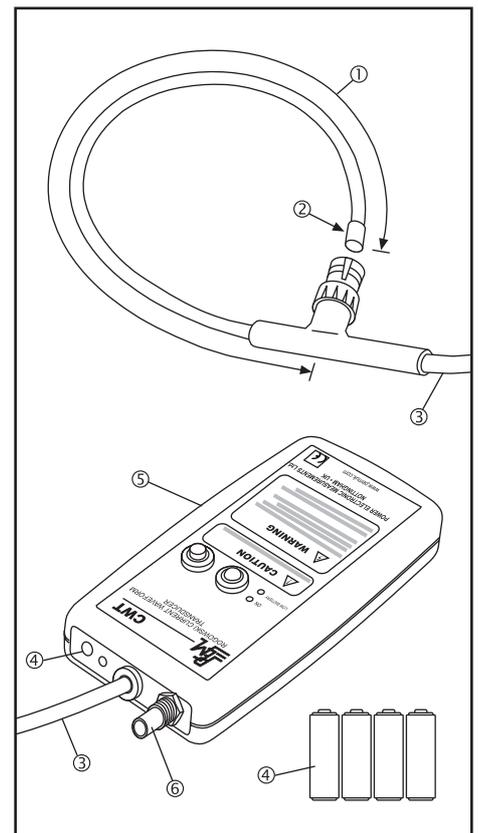
<b>TYPICAL ACCURACY</b>	Calibrated to UKAS ±0.2% with conductor central in the loop Variation with conductor position in the coil loop typically ±1%	<b>TYPICAL LINEARITY</b>	±0.05% (Full Scale)
<b>ABSOLUTE MAXIMUM VALUES OF di/dt</b> (kA/μs) (value must not be exceeded)	CWT 03, 06 CWT 015, 1N, 3N all other CWT's	<b>PEAK</b> 40.0 <b>PEAK</b> 20.0 <b>PEAK</b> 40.0	<b>RMS</b> 1.2 @ 70°C <b>RMS</b> 1.0 @ 70°C <b>RMS</b> 1.5 @ 70°C  (Further information available on request)

## COIL AND CABLE

① COIL CIRCUMFERENCE	300, 500, 700 or 1000mm
② COIL CROSS SECTION (max)	8.5mm - (14 mm with sleeve)
<b>PEAK COIL VOLTAGE ISOLATION</b>	10kV
Safe peak working voltage to earth. The coils are flash tested at 15kVrms for 60 seconds. The coil is supplied with a removable silicone sleeve which provides additional mechanical protection. Information about continuous use of the coils at high voltage can be obtained from PEM.	
<b>TEMPERATURE RANGE</b>	-20°C to 100°C
For de-rating due to temperature cycling please consult PEM	
③ CABLE LENGTH (from box to coil)	2.5m or 4m

## INTEGRATOR

④ <b>POWER SUPPLY</b>	
<b>B</b> Battery 4 x AA (1.5V standard alkali batteries) -plus- 2.1/2.5mm socket for 12 to 24V (±10%) DC input  Typical life 70hrs Battery inoperative with DC supply present	<b>R</b> Rechargeable battery 4 x AA (rechargeable NiMH batteries) -plus- 2.1/2.5mm socket for 12 to 24V (±10%) DC input  Recharge time 40hrs, Typical life 30hrs Battery is charged whenever DC supply present
⑤ <b>INTEGRATOR BOX DIMENSIONS</b>	H = 183mm, W = 93mm, D = 32mm
⑥ <b>OUTPUT SOCKET</b>	BNC (output impedance 50Ω - unit supplied with 0.5m BNC - BNC coaxial cable)
<b>MIN. OUTPUT LOADING</b>	100kΩ (for rated accuracy)
<b>TEMPERATURE RANGE</b>	0°C to 40°C



## ORDERING

Type + Power supply	/	Cable Length	/	Coil Circumference		
e.g. order code		<b>CWT30 B</b>	/	<b>4</b>	/	<b>700</b>

If you have any queries regarding the CWT or require specifications outside our standard ranges please do not hesitate to contact us.