Alexander Meier, DG6RBP

Digital mW meter

The revised version of a digital mW meter [1] is described below. Almost any diode detectors not needing a Townsend current can be used as sensors for this equipment. Depending on the detector, measurements up to 30GHz and beyond are possible. In addition to a measurement range between -45 and +20dBm, the equipment has additional interesting features such as an IEC bus interface.

1. Functioning

The DC output voltage from a diode detector is dependent on the RF input power. Due to the non-linear diode characteristic, this DC voltage follows the square of the input voltage for low input power levels (< -20dBm), it is therefore proportional to the input power. From an input power level of approximately 10dBm, the output voltage, in contrast, is proportional to the input voltage. In between, there is a gradual transition from one range to another. This condition makes a great deal of correction necessary, but this is very simply achieved with the help of a micro-controller.

The digital mW meter first amplifies the initial DC voltage from the diode detector. Four different amplification factors are available for this purpose. A switchable low pass filter suppresses residual modulation (AM), together with 50Hz interference. The DC voltage signal is then digitised using a 12 bit A/D converter. In order to avoid earth loops (50Hz hum), the pre-amplifier is isolated from the rest of the equipment (micro-controller, interfaces, power supply).

A rapid, 8032 compatible type from DALLAS is used as the micro-controller. This compares the measured detector voltage with a look-up table in order to determine the measured RF power. In this table, values from the calibration of the detector with an output voltage going in 1dB steps from 45 to +20dBm are saved in the EEPROM. There is linear interpolation between the 1dB calibration points. The readings are displayed with a resolution of 0.1dB or 0.5dB at very low input levels (below approximately 40dBm). The measurements are started at adjustable intervals (1/2/5) of between 10ms and 20s. If this triggering is switched off, the equipment starts a new measurement as soon as the previous one ends. Approximately 1,000 measurements a second can be carried out with this equipment.

An analogue recorder output was integrated, together with an IEC bus interface (laboratory standard). [2] contains a simple converter between the IEC bus

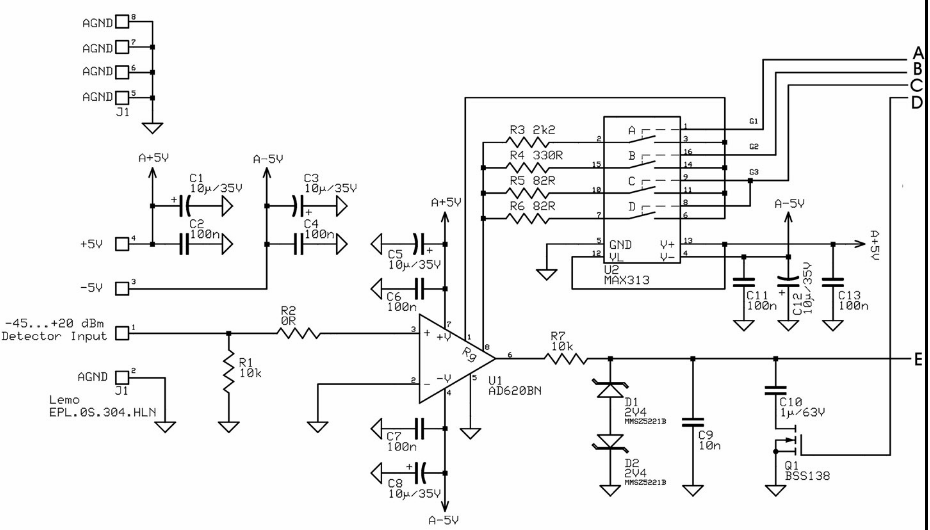

Fig 1: Input amplifier for the digital mW meter.

and the RS-232 serial interface.

However, the use of a micro-controller also brings some additional advantages to operating the equipment. It is possible to add an adjustable offset to the reading in order, for example, to take a directional coupler used in the measurement into account. Relative measurements using an adjustable reference level, or one which can be saved from current measurement, are possible. This also allows adjustment measurements to be carried out using a measuring bridge or a directional coupler. If the measured relative level corresponds to the return loss, the mW meter can use this to calculate and display the corresponding SWR.

An additional special feature is the switchable display from dBm and mW to dBµV and Volts (for 50Ω detectors).

The LCD display contrast can be digitally adjusted using keys on the front panel. The technical data from the equipment are summarised in Table 1.

2. Circuit description

The complete circuit diagram of the digital RF mW meter is shown in the Fig 1, Fig 2 and Fig 3. The micro-controller unit is not shown as this is outside the scope of the circuit diagram. Those interested can email the publishers for a copy of the circuit diagram.

The DC output voltage from the detector is fed to the pre-amplifier through a 4 pin precision socket and given a load of 10kΩ (R1). A ±5V supply voltage is also connected to this socket so that extensions can be used (e.g. special sensors).

The pre-amplifier used is an AD620 instrument amplifier from Analog Devices. The amplification here is adjusted between PIN 1 and PIN 8 here using a resistor, with a high level of amplification requiring a small resistor.

Using the U2 analogue switch, the ampli-

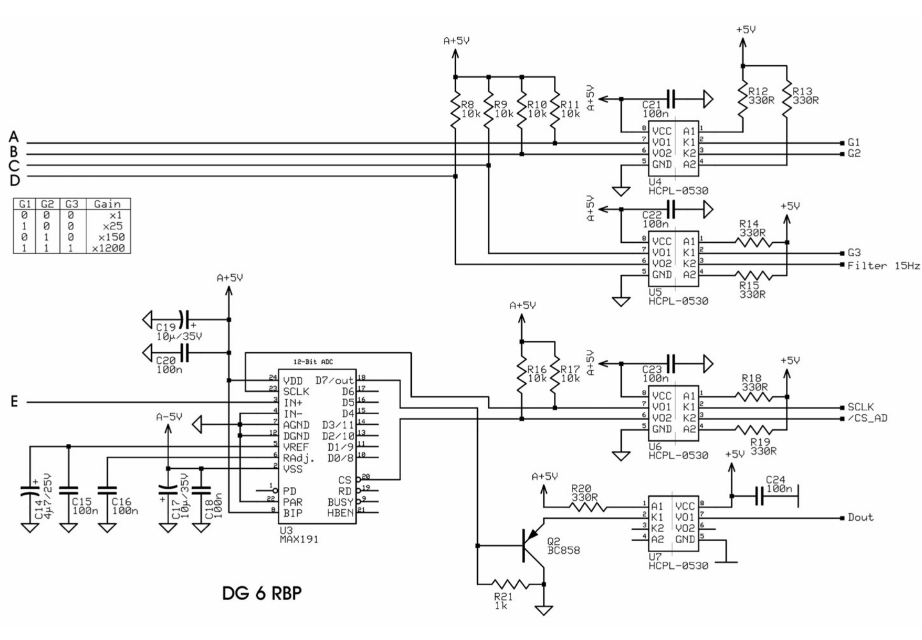

Fig 2: A/D converter for the digital mW meter.

fication can be switched between approximately 1200/150/25 and 1.

The AD620s offset voltage, even for an amplification of 1,200 is only a few mV at the output, so that it is sufficient to offset this from the measured voltage through the micro-controller.
The output voltage from the U1 instrument amplifier is compressed by means of R7, D1 and D2 and fed to the analogue/digital converter. In spite of the characteristics of the detector diode, a large input power range can be covered without switching the amplification using the A/D converter.

At two or less measurements per second, a 15Hz RC low pass (R7, C10) is automatically connected, with the help of the MOS-FET Q1. This suppresses any possible 50Hz interference.

The analogue/digital converter (U3) used is a MAX 191 from MAXIM. This is wired via PIN 8 for bipolar operation. The input voltage level from 0 to ±2048 mV is digitised to 11 bit accuracy (resolution 1mV). The twelfth bit signifies the polarity. Thus diode detectors with both positive and negative output voltages can be used.

The opto-couplers, U4 to U7, provide isolation between the pre-amplifier and the A/D converter from the rest of the digital section. This is absolutely necessary, since otherwise undesirable earth loops may occur (e.g. via an earthed test object and an earthed piece of equipment at the recorder output). The isolated earths are connected to one another using a high value resistor R39.

The recorder output is realised using the 12-bit digital/analogue converter (U8). The output voltage of this converter covers a range between 0 and 4,096mV in steps of 1mV. The software can be used to scale the relationship between the output voltage and the measurement re-

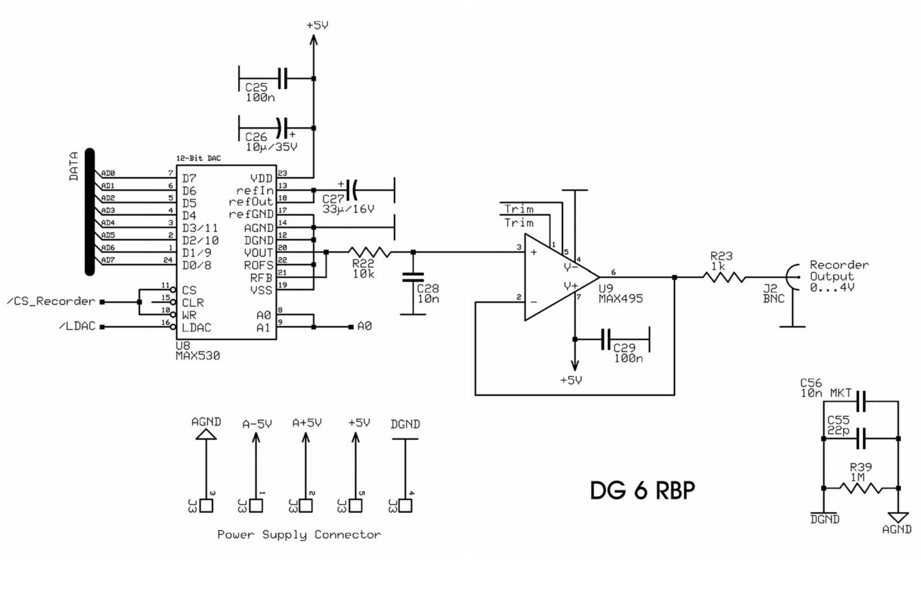

Fig 3: Recorder output for the digital mW meter.

sult. After a buffer and a 1kΩ series resistor, the voltage is available at the BNC socket on the rear panel of the equipment.

The control via the micro-controller is made up of the usual configuration: micro-controller, U12 address/data latch, U17 address decoder, an EPROM for the software and a RAM as memory. The calibration data and equipment settings are saved in the non-volatile EEPROM (U10), so that they are retained, even after the equipment is switched off. When the equipment is switched on again, the data is copied into the faster U14 RAM from the EEPROM.

The second U18 micro-controller is needed only for interrogating the keys. This makes it possible to run the software better, since not only must a keystroke be recognised but the pressure dwell too. A recognised and evaluated keystroke is serially transferred to the U11 controller at 4,807 Baud. The U18 keyboard controller already has a flash memory for its software integrated in the chip.

A two-line LCD display with background lighting is used for the display. The U15 digital potentiometer (10kΩ) is used to set the contrast.

The U19 latch serves to control the light-emitting diodes on the front panel. The resistors, R34 to R38, serve to limit the current for the LEDs.

The IEEE-488 interface consists merely of an IC and a quartz oscillator. The i7210 (U21) used is compatible with the earlier industry standard µPD7210 from NEC, which is no longer obtainable. Even the SN75160 / SN75162 driver modules, which are still difficult to obtain and are usually in SMD format are already integrated in the new i7210 IC.

The equipment address is written into the corresponding register of the i7210 when the mW meter is initialised. An 8MHz

Table 1: Technical data for the digital mW meter.

Usable power sensors	All diode detectors which need no Townsend current
Polarity	Positive or negative (reversible)
Frequency range	Determined by detector
Input impedance	Approximately 10 kΩ
Input socket	4-pole. Detector voltage, earth, ± 5V for special sensors
Stored calibration data	For a maximum of 7 detectors
Measurement range	- 45.0 to + 19.9dBm (or 62 to 127dBµV)
Measurement resolution	0.1dB (> -40.0dBm); 0.5dB (< -40.0dBm); Depending on detector!
Measurement interval	10ms to 20s in 1/2/5 steps Continuously repeating measurement (1,000 per second) Measurement can be halted by pressing key
Precision	Approximately 0.5dB (dependent on detector & cal.)
Filter	15Hz low pass filter (20dB / decade) automatic when 2 or fewer measurements per second)
Display range	- 99.9 to + 99.9dBm (or 7.1 to 206.9dBµV)
Display format	dBm and mW dBµV and Volts (referred to 50Ω) Relative to reference value Relative to reference value + SWR
Display resolution	0.1dB
Display speed LCD	4 measurements per second
Null balance	Automatic when key is pressed
Offset	Adjustable 99.9 to +99.99dB, switched on/off by key
Reference value	Storable from measurement in progress or adjustable from 99.9 to 99.9dBm
DC output	0 - 4 Volts corresponding to 99.9 to 99.9dBm 0 - 4 Volts corresponding to 99.9 to 99.9dB relative to reference value 0 - 0.8 Volts corresponding to 50.0 to + 30.0dBm
Interface	IEEE-499 (IEC bus) (SH1, AH1, T8, L4, SRO, RL2, PP0, DC1, DT1)
Power supply	+ 8 to 20 Volts DC, max. 500mA

Fig 4: Completed digital mW meter by DG6RBP.

quartz oscillator (U20) is used as the clock generator. However, the i7201 in the 40-pin housing has recently been discontinued. It is, though, still obtainable in the smaller SMD housing and can then be pinned into the 40-pin base with an adapter board.

A plug-in power pack which should deliver at least 500mA at 12V is used for the power supply. The diode D1 acts as reverse battery protection.

3. Literature

[1] Digital HF power measurement equipment;
Alexander Meier, DG6RBP, Paper read at 45th VHF Congress, Weinheim 2000

[2] Jirmann, Jochen: IEC-Bus-Interface, VHF Reports, issue 3/ 1999