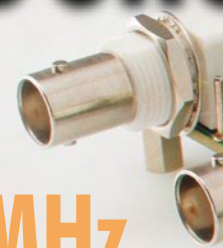


# RF Sweep Frequency Gene

## Measure filter response and check frequency spectrum from DC to 450 MHz



Gert Baars (The Netherlands)

**The instrument described in this article combines the functions of a sweep frequency generator ('wobbulator') and a spectrum analyser. In the SFG mode, it can be used to measure the frequency characteristics of selective components or circuits at frequencies up to 450 MHz. The spectrum analyser mode can be used to measure the outputs of circuits and equipment, as well as antennas.**

The measuring system described here consists of two parts: a hardware module in a separate enclosure with all the signal inputs and outputs, and software that runs on a PC under MS Windows. The measurements are displayed in graphic form on the PC monitor, and the user can configure all the variables and options as desired via the keyboard.

A major advantage relative to many commercial stand-alone instruments of this sort is the large screen area. In addition, the measured characteristics can easily be saved to disk or printed out.

Beside the two measuring modes already mentioned, the instrument can be used to generate a signal with a fixed frequency in the range of 5 kHz to 450 MHz, which means that it can be used as a test transmitter.

As the spectrum analyser is essentially a direct-conversion receiver, the instrument also includes an audio output. This allows it to be used to listen to AM or FM radio signals. A VFO (variable frequency oscillator) function is also included, which allows any desired offset frequency to be configured for the first post-mixer (IF, intermediate frequency) stage of the receiver.

The software also has an option for making measurements with a SWR bridge. An SWR (standing wave ratio)

bridge (which can be connected externally) can be used for direct measurement of the standing-wave ratio of a device such as a 50- $\Omega$  antenna.

### Block diagram

The original intention was to simply make a sweep frequency generator (SFG) for frequencies extending as far as the UHF (70 cms) band. However, the idea of adding a spectrum analyser function arose quite quickly. This is only natural, since an SFG already includes a large number of the elements necessary for a spectrum analyser, such as a DDS (direct digital synthesizer) IC, a logarithmic detector, and a microcontroller with an A/D converter and UART. The main additional elements that are necessary are a mixer and some IF filters. Of course, the software must also be able to make use of both functions.

The block diagram (**Figure 1**) thus represents two different circuits that can be selected by the control function. The control function, which takes the form of a microcontroller, is connected to a PC via a serial link, and it receives commands and parameters from the PC. Based on the received commands and parameters, the microcontroller executes tasks that generate data, which is then returned to the PC where

the data is processed and displayed by software running in the PC.

Thanks to this approach, the user can operate the entire system from the PC and the measured data is displayed in graphic form.

### Sweep Frequency Generator portion

The sweep signal for the instrument is generated by a direct digital synthesizer (DDS). The DDS operates with a reference frequency (REFCLK) of 1000 MHz, and it can generate signals up to 450 MHz with a step size of 0.24 Hz. As the DDS provides samples at a 1000-MHz rate, the output signal can be regarded from a mathematical viewpoint as being multiplied by 1000 MHz. This generates spurious products that make output filtering necessary, and this is provided here by a 450-MHz lowpass filter. As two signals are necessary because a local oscillator (LO) signal must also be supplied to the mixer, the filter is followed by a two-way splitter with an impedance of 50  $\Omega$ . The SFG ('wobbulator') output signal from the splitter has an amplitude of approximately  $-8$  dBm (90 mV<sub>eff</sub> into 50  $\Omega$ ), which makes it quite suitable for measuring the pass characteristics of a wide variety of filters. In the spectrum analyser mode, the wobbulator output is terminated in 50  $\Omega$  in order to avoid influencing

# Generator / Spectrum Analyser



## Technical Specifications

### Sweep Frequency Generator

#### Horizontal:

Maximum frequency: 450 MHz

Minimum usable frequency: 5 kHz

Sweep: any desired scan between DC and 450 MHz

Resolution: 1/650 of the scan width

Sweep rate: 0.2, 0.5, 1, 2, 5, and 10 s/scan

Linear or logarithmic frequency scale

#### Vertical:

Range: 0 to approx. -60 dB

Resolution: 1 dB

Accuracy: approx. 2 dB

Output: 50  $\Omega$ , -8 dBm

Input: 50  $\Omega$  or active probe with 1 M $\Omega$  // 4 pF input impedance

### Spectrum Analyser

#### Horizontal:

Maximum frequency: 450 MHz

Minimum usable frequency: 0.1 MHz

Sweep: any desired scan between DC and 450 MHz

Resolution: 1/650 of the scan width

Sweep rate depends on scan width, detection bandwidth and accuracy; range approx. 0.25 s to 30 s

#### Vertical:

Range: 0 to approx. -80 dBm

Resolution: 1 dB

Accuracy: Average  $\pm 2$  dBm (in part dependent on scan rate)

Detection bandwidths: 25 kHz and 100 kHz

Input impedance: 50  $\Omega$  or active probe (1 M $\Omega$  // 4 pF)

the amplitude of the LO signal for the mixer.

The SFG input (on the right in the block diagram) can be 50  $\Omega$  or an active probe with a input impedance of 1 M $\Omega$  // 4 pF, which is nice for working with filters because they often require a matching impedance much greater than 50  $\Omega$ . This way the attenuation

due to mismatching is much smaller, which means that the vertical measuring range is much larger. The probe also provides many other benefits with all sorts of measurement tasks for which low loading is desirable.

The signal on the SFG input is first preamplified. The resulting output signal closely approaches the maximum

input level (+17 dBm) of the subsequent logarithmic detector, which also increases the vertical measuring range.

The detector is followed by a low-pass filter to ensure that only the 'DC' component (in a manner of speaking) reaches the microcontroller's A/D converter.

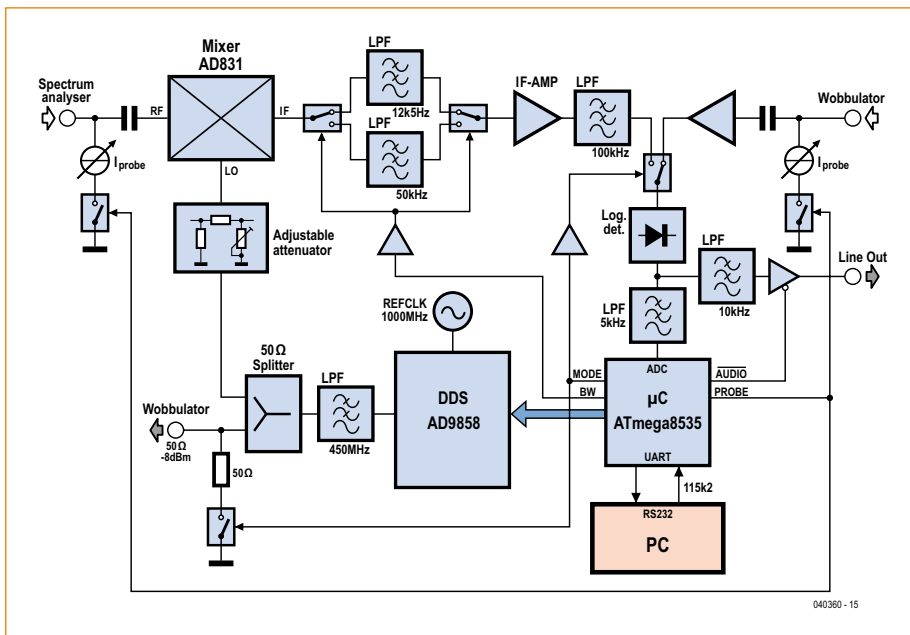


Figure 1. Block diagram of the sweep frequency generator / spectrum analyser.

Obviously, the frequency response of the device under test (DUT) can be measured by connecting the wobbulator output to the DUT input and the DUT output to the SFG input and then performing a frequency scan.

**Spectrum analyser portion**

The spectrum analyser operates on the direct-conversion principle. This provides a number of benefits. To start with, it allows the IF filters to take the form of lowpass filters, which are easy to make as DIY filters. Another important benefit is that the image frequency is referenced to the LO frequency, which has the significant effect of making the bandwidth twice as large as that bandwidth of the post-mixer filter. This way, bandwidths of 25 kHz and 100 kHz are obtained with 25.5-kHz and 50-kHz lowpass filters. The software ensures that the right measurement data is displayed. The input of the spectrum analyser is connected directly to the mixer. The type of mixer used here is marked by very high linearity. A preamplifier ahead of the mixer would only make things worse. The post-mixer filter is followed by an amplifier, which boosts the signal amplitude to a level that matches the range of the subsequent logarithmic detector. The same detector is used for the spectrum analyser and SFG functions by switching the signal paths according to the operating mode. The remaining hardware is the same as for the SFG, with the major

difference being found in the software for the spectrum analyser and sweep frequency generator functions.

**Schematic diagram**

**Sweep Frequency Generator input preamplifier**

The input stage of the SFG consists of a broadband amplifier in the form of an ERA-5 IC (IC1) from Minicircuits [1]. This 50-Ω stripline broadband amplifier was chosen for its high IP3 and 1-dB compression point. In simplified terms, this means that the input stage has good immunity to the generation of undesired spurious products in the presence of large input signals, which could cause false measurement results, but it can still supply adequate output power. The gain of the ERA-5 is a constant 22 dB from DC to 1000 MHz, which makes it more than suitable for the desired bandwidth of 450 MHz. This MMIC also has a noise figure that is low enough for our application.

**Detector**

In order to achieve a large dynamic measuring range, we decided to use a logarithmic detector. The Analog Devices [2] AD8307 (IC7) used here has a bandwidth of DC to well over 500 MHz, and it outputs a DC voltage that is proportional to the level of the input signal in dBm. The input signal range of this detector is approximately -75 dBm to +17 dBm. The maximum level (+17 dBm) is somewhat on

the high side, which is why the previously mentioned ERA-5 preamplifier is included in the circuit. Another important aspect of this logarithmic detector is that it can track fast changes in the input level. This is necessary to avoid an excessively long delay for sweep generation, so the time required to perform a sweep can be kept within reasonable limits.

A simple lowpass filter (R25-C83-R26-C84) after the detector prevents residual signal components from reaching the A/D converter.

**A/D converter**

The A/D converter is integrated in the microcontroller (IC12). This 10-bit successive-approximation A/D converter provides 10-bit conversion results with a conversion time of approximately 110 μs. It can also operate at higher conversion rates, but this comes at the cost of accuracy. The advantage of 10-bit resolution is that if desired, the vertical scale can be enlarged while still maintaining relatively high accuracy. As a result, a vertical scale of 25 dB still has the same accuracy as a vertical scale of 100 dB.

**Microcontroller**

The hardware is controlled by a microcontroller in the form of an Atmel type ATmega8535 [3]. This 8-bit RISC microcontroller can achieve 16 MIPS (million instructions per second) with a clock rate of 16 MHz. However, we use a 14.7456-MHz crystal here so that the baud rate of the integrated UART can be set to exactly the desired value of 115,200 baud. Among other things, this microcontroller features 8 kB of flash program memory, an 8-channel / 10-bit A/D converter, 512 bytes of RAM, and a serial UART, which make it an outstanding choice for this application. The link between the UART and the COM port requires level conversion in order to adapt the signal levels of the UART (+5 V / 0 V) to signal levels of the COM port (±12 V). A Maxim [4] MAX232 (IC11), which requires only a few external components, is used for this purpose.

**DDS**

The sweep signal for the SFG output and the LO signal for the spectrum analyser mixer are generated by an Analog Devices AD9858 (IC12). The outstanding feature of this particular DDS IC is its high clock speed, which extends to 1 GHz. This very advanced DDS makes it easy to generate fre-

quencies up to 450 MHz with 32-bit precision, which amounts to a step size of 0.233 Hz. In addition, this 100-pin DDS IC has extremely low phase noise (more than 145 dB below the carrier level). It can also be controlled in parallel or serial mode. Even the serial mode is more than fast enough for use as a sweep generator. Another feature of this IC, which is not used in this design, is that it can store four externally selectable frequency profiles for ultra-fast frequency hopping. Another noteworthy aspect is that the DDS chip must be powered from 3.3 V, while the maximum dissipation can be as much as 2 watts.

In addition to the DDS, the AD9858 houses a PLL and a mixer. They are also user-programmable, but they are disabled in this application by means of software initialisation and not used in the circuit in order to avoid unnecessarily increasing the power dissipation. The full-scale output current of the DDS is set by an external resistor. Here we chose a safe figure of 20 mA. According to the manufacturer, this yields the least amount of spurious products.

#### DDS reference clock

One thing that initially appeared to be a problem was generating a stable 1-GHz reference clock signal for the DDS. Solutions such as a crystal oscillator with multipliers or an extra PLL appeared to require an undesirable number of additional components, while a simple free-running oscillator might drift too much. Consideration was also given to using the internal PLL of the DDS IC for this.

We discovered that a 1000-MHz SAW (surface acoustic wave) resonator is available from Tai-Saw [5], with type number TC0306A. A supplementary benefit of a reference oscillator built around this sort of resonator (X2) is that it does not have to be adjusted, and any small deviations can easily be compensated in the software (a calibration feature is provided for this).

#### DDS output filter

As already mentioned, the digital technique used to generate DDS signals inherently causes spurious products to be generated as well. There are also residual components of the 1000-MHz clock in the output signal. A 450-MHz, seventh-order Chebyshev filter was developed to eliminate them. The inherent impedance of the filter is 50  $\Omega$ , and it has four trim capacitors that must be used to adjust it for

proper response. The chance of deviations would be too large if fixed-value components were used here. Incidentally, the adjustment is not difficult, and it can be performed directly with the aid of the sweep frequency generator, so no additional instruments are needed. A certain amount of ripple can be seen on the screen when the filter is properly adjusted, and there is some roll-off due to the reduced sensitivity of the AD8307 detector as well as the reduced amplitude of the DDS signal. However, the software has a calibration function that can be used to restore a perfectly straight-line characteristic.

The filter is followed by a simple 50- $\Omega$  splitter to yield two output signals: one for the wobulator output and the other for the LO input of the spectrum analyser mixer. As both outputs of the splitter must always see a 50- $\Omega$  load, the microcontroller connects a 50- $\Omega$  termination resistor across the wobulator output when the spectrum analyser is being used.

#### Mixer

Very high requirements are placed on the mixer for the direct-conversion spectrum analyser. A balanced-diode mixer is far from being good enough, due to the low isolation between the ports, and its switching behaviour is an even larger drawback. The multiplication of the LO signal with the RF signal must be as linear as possible, which is only possible with a good active mixer.

An outstanding mixer for this application is the AD831, once again from Analog Devices. This special low-distortion mixer produces very low distortion even with relatively large input signals, it has sufficient isolation, and it can be used with input and LO signals up to 500 MHz. With this mixer, the LO input is usually driven into saturation. For this purpose, it has an internal amplifier for the LO signal. However, the LO signal can be supplied via an adjustable attenuator so that the signal amplitude can be set to exactly the level that yields the least distortion. This can be done quite easily by scanning a signal in spectrum-analyser mode. If the LO signal amplitude is too high, a spike will be seen at  $f/3$  of the input signal. The adjustable attenuator can be set to reduce the level of this spike until it just disappears in the noise floor. It is important to reduce it to just this level and no further, as otherwise the mixer will atten-

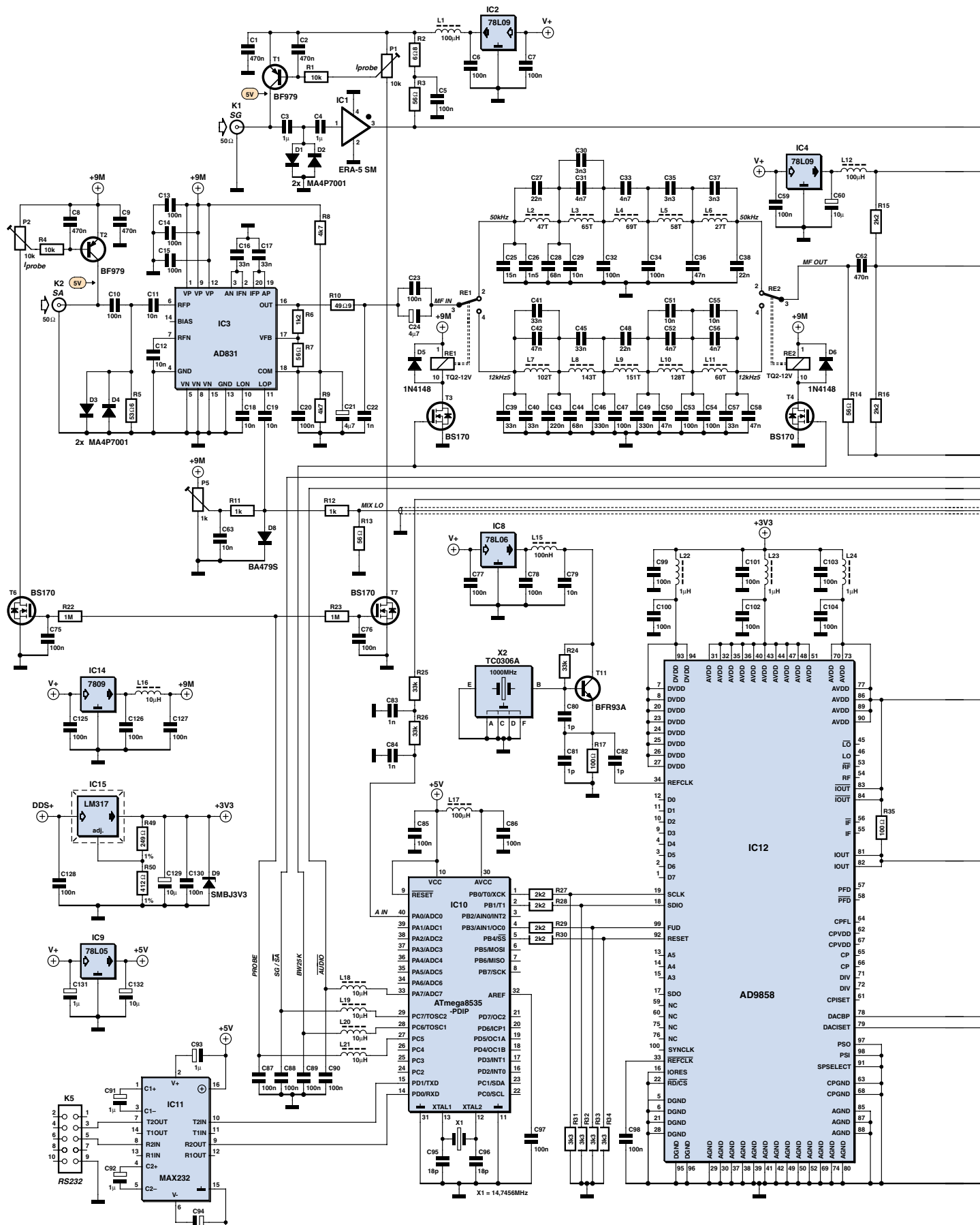
uate the signal more than necessary. The adjustable attenuator is implemented using a PIN diode so that it can be used at high frequencies.

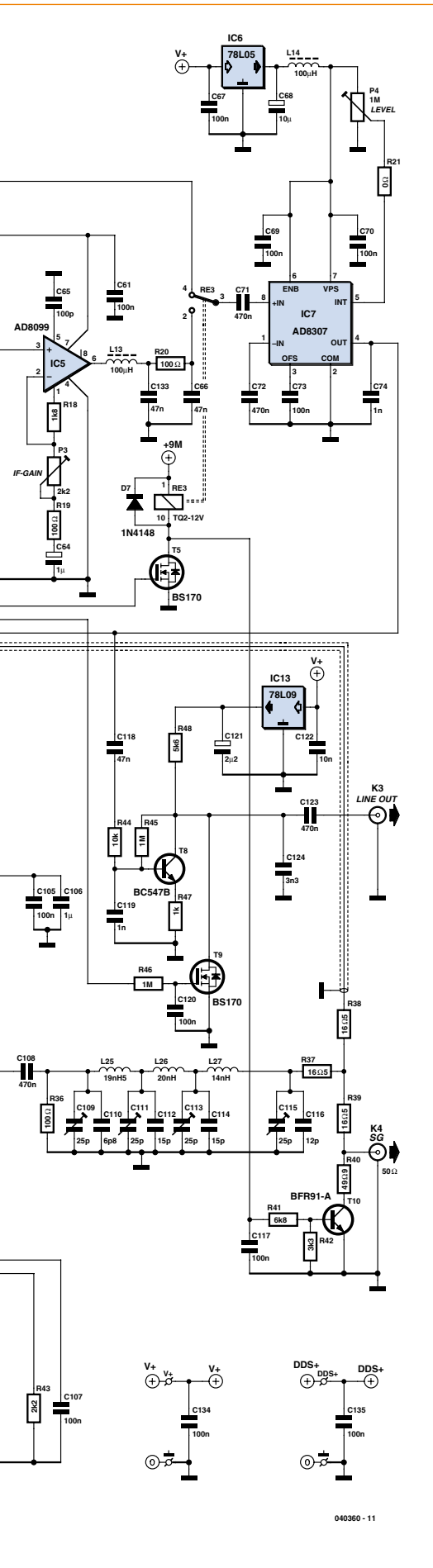
The mixer also has an internal output amplifier, which we are happy to use here because it is better to amplify the signal before the IF filter, since the noise voltage is directly proportional to the bandwidth. This allows a lower amount of IF gain to be used, which also results in less noise. In this way we manage to achieve a noise floor of approximately -80 dBm. The mixer must have an output impedance of 50  $\Omega$  in order to properly match the impedance of the IF filters. The coupling capacitors at the output determine the lowest intermediate frequency, and they must have a relatively high value. Otherwise a visible dent in frequency response will occur when the scan width is fairly small relative to the bandwidth of the IF filter, due to the direct-conversion principle. With larger scan widths, which of course will most often be used in practice, this phenomenon is compensated in software and the display shows taut, needle-shaped frequency lines.

#### Post-mixer filters

The filters 'behind' the mixer determine the bandwidth of the spectrum analyser. We decided to use two selectable filters with bandwidths of 12.5 kHz and 50 kHz, respectively. Due to the direct conversion principle, the bandwidth is doubled to 25 kHz and 100 kHz. These filters should be as steep as possible. The desired properties can be approximated with 11<sup>th</sup>-order elliptical filters – which means a flat amplitude characteristic up to the corner frequency, followed by a very steep skirt so that the base width is small enough for this application, even at -80 dB. We achieved this by winding our own coils on toroidal cores. The 14-mm 4C65 cores that we used have a  $\mu_r$  specification of 125. This is not especially large for a toroidal core, but it must be said that toroidal cores with very large  $\mu$  values are almost always made from a material with a relatively high ohmic resistance. This results in core losses, which in turn reduce the Q factor. Here we used ordinary MKT capacitors with good results. A supplementary benefit of using toroidal cores is that they are usually rather insensitive to external fields.

The two IF filters are selected by a set of TQ-2 relays operated by the micro-





controller in response to a command from the PC application.

**Post-mixer amplifier**

Like the mixer, the amplifier that follows it must have very good characteristics. We chose the AD8099, which is listed as an opamp with extremely low distortion and noise. This opamp – which is also affordable – is made by Analog Devices. It has an enormous bandwidth of no less than 3.8 MHz, which is not especially important for this application but certainly worth mentioning. The very low noise contribution of the IF amplifier is especially important because it keeps the noise floor of the spectrum analyser as low as possible. The noise is reduced even further by dimensioning the input section of this IC for an AC impedance of 50 Ω, which matches the impedance of the IF filters. A simple lowpass filter is located at the output of the intermediate frequency amplifier to restrict the noise spectrum.

**Active probe**

An active probe is included because 50 Ω would be too much of a load for many measurements. It has been kept as simple as possible and consists of only five components (Figure 4). It can thus be built into a small external enclosure, such as the body of a ball-point pen or felt pen.

The probe has an input impedance of 1 MΩ // 4 pF and a maximum usable frequency of about 450 MHz, and it can be used with the spectrum analyser as well as the SFG.

As the probe attenuates the signal slightly, a separate calibration button is included in the software to compensate for all the deviations. The calibration data is saved automatically in specific .ini files so it can be reused. This means that the calibration only has to be performed once. When the instrument is switched to work without the probe, the standard calibration file is automatically read from disk and used.

For convenience, the probe is powered directly from the hardware. An approach using chokes is not desirable here. Large chokes are necessary for low frequencies, and they usually have high internal and stray capacitance. A simpler and better solution

is to power the probe with a DC current. For this purpose, a switchable current source is provided at the SFG input and the spectrum analyser input, in the form of a PNP transistor (T1 or T2, respectively) with an adjustable collector current that can be switched off by the microcontroller, since a DC current could have undesirable effects when measurements are made without the probe. The ‘Use Probe’ command in the Options menu of the PC application switches the probe supply on or off. In principle, any transistor can be wired as a current source, but here the collector capacitance should be as small as possible. We thus selected a UHF transistor, in this case the BF979. The probe current from each transistor can be set to approximately 14 mA by adjusting the potentiometer connected to the base. At this current, the DC voltage on the collector of the transistor is approximately 5 V.

**Input protection**

The inputs of the spectrum analyser and SFG are protected against excessive input signals. For this purpose, two PIN diodes (type MA4P7001) are connected to each input in reverse parallel. These PIN diodes from M/A-COM [6] have a blocking capacitance of 0.7 pF and the threshold voltage of each diode is 1 V, so the input signal is limited to 2 V<sub>pp</sub>. This corresponds to +10 dBm, which both inputs can handle easily. Each diode can dissipate 3 W for a relatively long time, or 10 times this much for a short time.

In practice, this means that the diodes will still do their job if (for example) the output of a 25-watt transmitter is accidentally connected directly to the spectrum analyser input. This is because relatively modern transceivers automatically and quickly reduce the output power in such situations due to the resulting low load impedance. The diodes have a very low impedance if they are overdriven, so almost all the supplied power is reflected. The author suspects that the input capacitors will fail before the diodes if too much power is applied to the input, although arguably he has not tested this. It is thus advisable to use SMA devices with a relatively small package size for the series capacitors. Then if an accident occurs, you only have to replace these capacitors.

**DDS power supply and cooling**

The DDS should be powered from a 3.3-V supply, and its current consumption

Figure 2. The resulting schematic diagram is rather extensive. The DDS IC occupies a central position here.

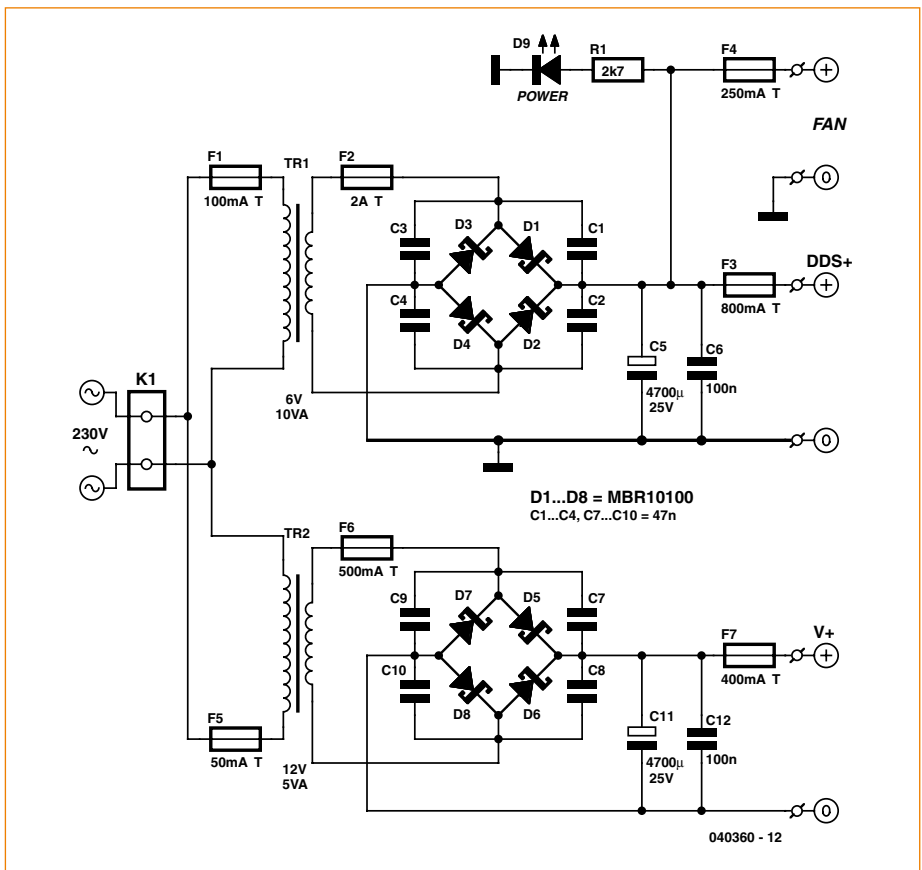


Figure 3. Two power supply transformers with rectifiers and smoothing capacitors are located on a separate power supply board.

is approximately 600 mA. This means that the IC must dissipate around 2 W of heat. For this purpose, the IC has a thermal pad on the bottom of the package, which is supposed to make contact with thermal vias in the PCB that transport the heat to the bottom of the board. The necessary vias are thus present in the PCB layout. In order to do this properly, you need a reflow soldering oven (as described in another article in this issue). The supply voltage for the DDS IC is provided by an LM317 (IC15) set to an output voltage of 3.3 V. The input voltage is approximately 7 V, so the voltage

regulator must dissipate around 2 W. It is fitted with a small heat sink for this purpose. To increase the working life of all this, the author fitted a small fan in his prototype to provide forced-air cooling. The voltage regulator and its heat sink are located close to the DDS IC so that they can both be cooled by the same fan.

**Mains power supply**

A separate power supply PCB has been designed for the main power supply. It holds two mains transformers along with the necessary rectifier diodes and capacitors (Figure 3). The power supply board provides supply voltages of 7 V and 12 V. A separate connector is provided for a fan if desired.

**Software**

The software consists of two programs: (1) firmware (i.e. object code created from assembly language) for the microcontroller in the hardware and (2) a Delphi program for the PC. Here it should be noted that the majority of the tasks are performed by the PC program. Logarithmic calculations, for example, are very cumbersome in

assembly language, so the Delphi program performs all intensive computations and only sends simplified parameters and commands to the ATmega microcontroller, whose primary task is to control the hardware.

**Communication protocol**

A separate protocol was created for the communication between the PC program and the firmware controlling the hardware. For each communication session, the PC sends a command to the microcontroller, which acknowledges it by returning the command (echo). After this, the PC sends a number of parameters, such as the start frequency, scan parameters, step delay, step size, and so on. The microcontroller waits for the PC to issue a 'start' command before it performs a sweep using the most recently sent parameters. The results from the A/D converter are sent to the PC during the sweep. Some parameters are always the same, such as the scan width and the two fixed IF bandwidths. These parameters are defined as constants.

In this way, specific commands and parameters are sent to the hardware after certain options or actions have been selected on the PC, and the hardware is then instructed to perform the actual measurement.

The commands have been assigned simple names, such as 'hello', 'start' and 'data', and the software sees them as single-byte codes.

**Assembly-language program**

The assembly-language program used to build the microcontroller firmware begins in the usual manner with a reset interrupt routine. Among other things, this routine initialises the I/O ports, the A/D converter, the UART, and the DDS. This means that their parameters are set according to the desired configuration.

The main program, or 'mainflow', starts after the reset routine. The only thing mainflow does is to periodically check the UART receive buffer to see whether any data has been received. If it has, the program checks to see which command is involved, which determines the subsequent course of action. The most important routines are the ones that execute a wobulator sweep or a spectrum analyser sweep and send a frequency word to the DDS. There are also several auxiliary routines, such as timer functions, starting and reading an A/D conversion, etc.

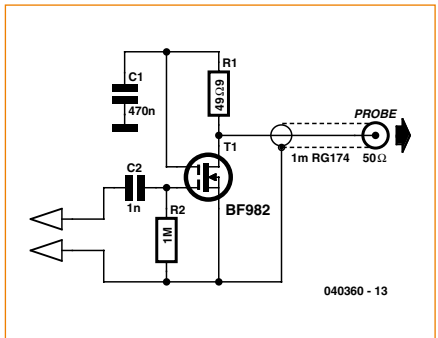


Figure 4. The active probe comprises only five components.

## Delphi program

The main task of the Delphi program developed for this project (**Figure 5**) is to display the measured characteristics. Delphi provides outstanding graphics capabilities, such as procedures for drawing lines. Basically what the program does is to send commands and data to the hardware and then read in the measurement data. This data is collected in a buffer, and a graphic is generated after all the data has been received.

The program can also send the graphics to the printer or save them to disk so they are stored for examination or use in documentation later on.

The program has a menu bar with several options, such as selecting a frequency scale graduated in hertz, kilohertz or megahertz. You can set the start and end frequencies, or you can opt to set the centre frequency and scan width instead. The latter option is particularly convenient for measuring filters when the centre frequency is known.

The Options menu lets you choose the speed of the spectrum analyser scan. The choices here are Slow, Normal and Fast. You can thus choose to scan faster with somewhat lower accuracy in order to obtain a quick impression of the spectrum, such as for measuring signals received from an antenna.

You can also select a linear or logarithmic horizontal scale for the sweep frequency generator. The logarithmic scale gives a better picture of the steepness of filters, for example, while the linear scale gives a better indication of measurements with a narrow scan, such as measuring the characteristics of ceramic or crystal filters.

The Options menu also has a calibration function. You can calibrate the frequency scale, for example by scanning a signal with a known frequency. After you click the point where the centre frequency should be, the actual frequency of the DDS reference oscillator is known, and it is stored immediately in a calibration file. The vertical scale can also be calibrated with and without the probe. This also takes only a mouse click, after which the calibration data is stored for subsequent use. In principle, calibration only has to be performed once, but there is no harm in recalibrating the instrument occasionally, since component values tend to drift over the course of time.

Another option is 'Use Probe'. If you click this option, the current sources for the active probe are enabled and

the calibration file for the probe is read in and used as long as the probe is enabled. Yet another option is 'Adjust LPF'. If you tick this option, the maximum frequency is set to 500 MHz instead of the usual 450 MHz. You can use this to perform a 500-MHz scan in order to adjust the DDS output filter for 450 MHz. The details of this are described in the adjustment procedure, which is included in the supplementary documentation for this article available on the Elektor website as document 040360-W.

In addition to the graphic display and the menu bar, the Delphi program has several Edit windows. They can be used to enter numbers, such as the frequency and decibel (dB) values that determine the scale graduations for the graphic display. There are several buttons on the screen for starting and stopping scans. There are also 'radio buttons' for setting the scan rate and the bandwidth of the spectrum analyser. Most of the program's user-interface functions can be selected and used with the mouse.

When the Delphi program is closed, certain settings (including the COM port settings) are saved automatically in a file called 'Settings.ini', which is located in the folder containing the main program. These settings are automatically read and restored when the program is started again, so they do not have to be entered anew each time.

## Scanning principle

The sweep frequency generator and the spectrum analyser both work with a scan width of 650 frequencies. This is not especially significant for the SFG, but in the case of a relatively broad scan with the spectrum analyser the frequency step equal to  $(f_2 - f_1)/650$  may be larger than the post-mixer bandwidth.

For instance, the step size is nearly 700 kHz with a scan from 0 to 450 MHz. The problem with this is that it would be easy to miss some signals. This is solved by having the hardware perform 'sub-scanning'. This means that the hardware independently performs a scan between two successive frequency values. With a scan of 0 to 450 MHz and a detection bandwidth of 25 kHz, the hardware must execute 28 steps ( $700/25$ ) for each X coordinate. In this case the microcontroller determines the largest measured value, which is then sent to the PC.

This method is perfectly satisfactory, but it costs a lot of time. The scan time for 450 MHz with a 25-kHz bandwidth can easily be more than 30 seconds. However, you can use the 'SASpeed' command in the Options menu to increase the scan speed. This option is intended to be used to obtain a quick impression of a spectrum by accepting lower accuracy. With this option, a scan from 0 to 450 MHz with a bandwidth of 100 kHz takes only 3 seconds. Scan rates with smaller scan widths are proportionally faster, reaching as much as several scans per second.

## More information

As this is a complex project with considerable scope, we have put all the practical information (such as construction, adjustment, components list, command summary and the software user's guide) in a separate document, which can be downloaded free of charge from the Elektor website (no. 040360-W). The PCB layouts (040360-PCB) and PC software (040360-11) are also available on the website. A pre-programmed microcontroller is available for this project (no. 040360-41), and the circuit boards will be available in due course from [www.ThePCBShop.com](http://www.ThePCBShop.com).

(040360-1)

## Internet Links

### [1] Minicircuits:

[www.minicircuits.com](http://www.minicircuits.com)

### [2] Analog Devices:

[www.analog.com](http://www.analog.com)

### [3] Atmel:

[www.atmel.com](http://www.atmel.com)

### [4] Maxim:

[www.maxim-ic.com](http://www.maxim-ic.com)

### [5] Tai-Saw:

[www.taisaw.com](http://www.taisaw.com)

### [6] Ma-Com:

[www.macom.com](http://www.macom.com)