Æ20401
5.8 GHz Frequency Counter / Power Meter

Assembly and Operation Manual

REV 3.0 EN

© 2014 Ascel Electronic

Table of Contents

Safety Information....ii
Handover of a Device Built From a Kit....iv
Intended Use....iv
ESD Warning....v
AE20401 5.8 GHz Frequency Counter / Power Meter....1
Circuit Description....2
Soldering....4
Component Reference....6
Assembly....14
Adjustment of the input amplifier....18
Troubleshooting Checklist....20
Power Supply....22
Case Mounting....23
Operation....25
Circuit Diagram....44
Bill of Materials....46
Component Placement Diagram....49
Data Interface....50
Specifications....53

Warning

Please read this manual before you assemble and use this kit. Keep it accessible for all users at all times.

Safety Information

Know and follow the applicable regulations for electric devices in your region. In Germany, these are especially VDE 0100, VDE 0550/0551, VDE 0700, VDE 0711 and VDE 0860. Pay attention to the following safety advices:

• Disconnect the power supply before opening the case.

• Work on devices only if you made sure that they are disconnected from any power supply, and any possible charge inside is discharged.

• Devices must only be used if they are mounted in a case in a way that prevents the user from touching any live wires or parts. Disconnect the device from its power supply during assembly.

• Always check the power cords for breaks or damaged insulation. Replace any defective parts immediately.

• Seek advice from a qualified expert if you are not sure about any specific value of a part, an installation procedure, or how to connect accessories.

•Always check if the device is suitable for the intended purpose before putting the unit in use. Seek assistance from a qualified professional or the manufacturer if you are not sure.

• The manufacturer assumes no liability for errors made during assembly or operation.

• Devices that need a supply voltage greater that 24V may be assembled by professionals only, to avoid hazards from improper assembly.

• In schools, educational institutes or workshops, the use of this unit must take place under the supervision of qualified staff.

• Do not put this unit in use in an environment where the risk of fire or explosion or explosive gas, vapor or dust is present.

• If the unit must be repaired, use original parts only. The use of inappropriate parts may lead to a safety risk.

• Avoid working alone.

• Keep electronic parts away from children.

• Do not replace parts with such that does not meet the required parameters. For example: never replace a fuse with another one with higher nominal current!

• Other regulations may apply. Please check the local safety regulations for assembling electronic devices.

Handover of a Device Built From a Kit

(in countries where applicable)

If you hand over a device built from a kit, you legally become the manufacturer. This mean you are responsible for complying with the appropriate regulations for electronic devices. All accompanying papers, in particular this manual, must also be passed over. Where necessary (for example in the European Union) you must also publish your identity to the consignee.

Intended Use

(in countries where applicable)

The intended use of this device is measuring frequencies and power within the given limits.

• Other uses are not approved!

ESD Warning

What is ESD?

Warning symbol for an electrostatic sensitive device

ESD (*Electrostatic Discharge)* is the sudden flow of electricity between two objects caused by contact or an electrical short. It can reach very high voltages of many kV. In some cases even over 100kV!

Causes of ESD

The main cause of ESD events is static electricity. Static electricity is usually generated through tribocharging, like walking on a rug, ascending from a fabric seat, removing some types of plastic packaging or using non-ESD compliant tools.

Danger of ESD

The high voltage pulse can easily destroy electronic parts. ICs and FETs are very sensitive to high voltage. **Even a short, single touch may destroy a part!**

How do I prevent damage due to ESD?

Always ground yourself while working with electronic parts. A grounded conducting wrist strap and proper anti-static work surface mat will help prevent ESD damage. Also make sure that the soldering iron is grounded and ESD-safe.

AE20401 5.8 GHz Frequency Counter / Power Meter

The AE20401 combines three different functions:

- A frequency counter, that range from mHz resolution with reciprocal counting algorithms to 5.8 GHz with the optional Channel B Module

- A pulse counter (Channel C)

- And a power meter (optional Channel PWR Module) that can measure from -55 dBm (3 nanowatt) to +30 dBm (1 watt) in the range from DC to 500 MHz. The value of external attenuators can be included in the readings.

It can measure Frequency/Period (Channel A/B) and RPM (Channel A). The number of pulses per revolution is adjustable. Offset and Smooth functions and selectable Trigger Edge extends the possible applications even further.

The USB interface[1] allows remote control of the frequency counter with the included software. The easy, plain text command protocol allows simple integration with external tools and systems. Every single function of the device can be remote controlled.

All SMD (Surface Mounted Device) components are already soldered, so the kit is also suitable for beginners in electronics. The comprehensive manual should help answer all questions that may arise during assembly.

Please read the complete manual (especially if you are not yet experienced in electronic engineering) before building the kit.

1 *optional*

Circuit Description

The circuit diagram of the AE20401 can be divided into several parts, which are described here.

The digital part is based on microcontroller IC1. IC1 controls all functions, computes the readings, and drives the LCD. The USB port is handled by the FT230X UART-USB Bridge (IC5). IC8 is the 2.5V reference for the ADC (analog to digital converter) that is used to convert the analog output of the Power Meter Module to a digital value.

The 5V digital supply comes from the linear regulator IC4. D1 protects IC4 from reverse polarity of the input voltage. Decoupling capacitors are placed next to all ICs. Each module has their own power regulation and decoupling capacitors on their own boards.

Channel A/C input circuitry: the DC offset is removed from the signal first. Then it is impedance matched and fed to the input amplifier. D2/D3 limit the signal in case of input overload. P1* is used to attenuate it. A high-speed comparator (IC6) with hysteresis is then used to compare the signal against a reference voltage. (see chapter "Adjustment" for details).

Now a 5Vpp square wave that is the same frequency as the input signal is available which can be processed by the digital (logic) ICs. Along with the signal from Channel B, which is already divided by 500 in the module, it is divided by 2 by a high speed flip-flop (IC2), then further by 8 by a 4bit counter (IC3).

Now, all these signals are routed to a multiplexer (IC7), where three signals are available: the comparator output from Channel A, the divided-by-16 signal, and the divided-by-1000 signal from Channel B.

The microcontroller selects one of these signals, depending on active channel and mode, which is processed to create a reading.

The analog output from the Power Meter (Channel PWR) is converted to a digital value by the microcontroller's internal ADC. This digital value is then used to calculate the power.

Since the Channel B Module uses 3.3V internally, voltage dividers on the data lines (R17/R19, R23/R20 and R22/R21) reduce the amplitude from 5V to 3.3V.

The external input (EXT) is protected against overvoltage by R15 together with D4/D5.

The separately drawn CLK footprint can accept either a standard crystal oscillator or the optional 1ppm TCXO Module.

R2 is a high power resistor capable of withstanding short overload events on Channel A/C without damage – **however, it is important not to exceed the specified maximum limits, as higher input voltages may damage the frequency counter!**

Soldering

Please read the following pages if you are not yet experienced in soldering. Good soldering is a matter of practice! Practice on old boards until you feel confident before assembling the kit.

• **The parts are mounted on the silkscreen side of the PCB. Except parts whose designators ends with an asterisk (like S1*). These are mounted on the other side!**

• Do not inhale the fumes from the flux! Wash your hands after soldering! Wear protective glasses!

• If you use additional flux, make sure it is suitable for electronics use! Non-suitable flux may contain acid which will damage the traces on the PCB over time.

• Try to solder fast. Heating up for too long may damage the components and the board.

• Solder wire with a diameter between 0.5-0.75mm (0.02"-0.03") is most suitable for through-hole components. Lead solder is easier to use than lead-free solder.

• A clean, non-oxidized tip is essential for good soldering. Use a wet sponge or a metal wool tip cleaner to regularly clean the tip. The metal wool cleaners are superior to a wet sponge as there is no temperature shock.

• When soldering active components (ICs, Transistors, LEDs...), it is very important to prevent overheating the components. They should be soldered in no more than about 5 seconds. In addition, it is important not to confuse the polarity! See the next chapter on individual component types and their correct orientation.

• To solder:

1. Use the tip of the soldering iron to simultaneously heat up the PCB and the component leg.
2. Add solder. It should melt around the component leg.
3. Wait a moment. Do not move the part you just soldered for a few seconds while it is cooling down. Moving it may cause the solder joint to crack.
4. Then remove the iron. With lead solder, the solder joint should be glossy.

• After soldering, use side cutters to cut the leads straight above the solder joint.

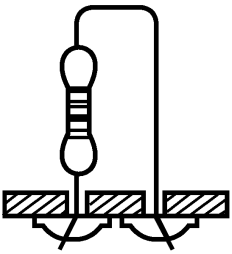
• After you are finished, check all components for correct placement and orientation. Also, check for unintentional shorts on the board. Small solder leftovers may cause shorts which can damage the board or the components.

• Use isopropyl alcohol (IPA) or a specific PCB cleaner fluid to remove flux residues. Flux is corrosive and should not remain on the board.

Component Reference

1 Resistors

To save PCB space, the resistors are mounted standing. To install:

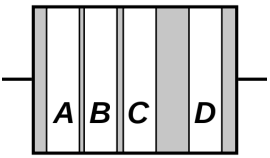


1. Bend the leads in form and put the resistor through the corresponding mounting holes.
2. Bend the leads aside to prevent the resistor from falling out.
3. Solder it accurately on the back side.
4. Cut the remaining leads above the solder joint.

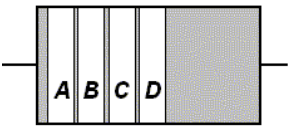
The resistance value is given with colored bands on the resistor. The code consists of four, five or six bands. With four bands, the first two are the base value (see table below), the third is the multiplier to the base value and the fourth is the tolerance. Five-band code uses the first three bands for base value. With six bands, the sixth is the temperature coefficient. The resistor value is:

base value * multiplier [± tolerance]

There are two possible arrangements for the bands order:



Type A



Type B

Color Codes:

Color	Digit	Multiplier	Tolerance ± in %
None	-	-	20
Silver	-	10^{-2}	10
Gold	-	10^{-1}	5
Black	0	10^{0}	-
Brown	1	10^{1}	1
Red	2	10^{2}	2
Orange	3	10^{3}	-
Yellow	4	10^{4}	-
Green	5	10^{5}	0.5
Blue	6	10^{6}	0.25
Purple	7	10^{7}	0.1
Grey	8	10^{8}	0.05
White	9	10^{9}	-

2 Capacitors / Electrolytic Capacitors

Capacitors are soldered the same way as resistors. **Electrolytic capacitors are polar. They must be mounted in the correct orientation! They will be destroyed when installed in reverse polarity and may even burst!**

Please keep in mind that different manufacturers mark the polarity in different ways. The marking may represent the positive or the negative terminal! The actual polarity (+ or -) is printed inside the marker band that points at one of the leads.

Capacitance Identification

A three-digit number without letters is the capacitance in pF, calculated this way: $a*10^b$ where a are the first two digits and b is the third digit (105 become $10*10^5$ pF = 1µF). One- or two-digit numbers states the capacitance directly in pF. A number including the letter "n" is the capacitance in nF, where 3n9 is 3.9nF.

Upper-case characters denote the tolerance according to this table:

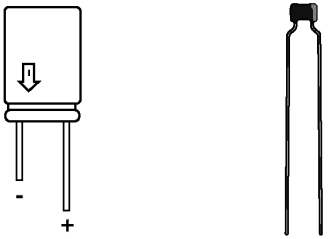
B	C	D	F	G	H
±0.1pF	±0.25pF	±0.5pF	±1%	±2%	±2.5%

J	K	M	S	Z	P
±5%	±10	±20	+50% -20%	+ 80% - 20%	0% -10%

A number following up indicates the electric strength.

Sometimes you may encounter a number like 0.5, this is the capacitance in µF.

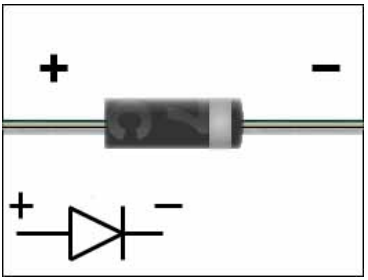
Electrolytic capacitors are usually labeled with the capacitance in µF straight. µ is where the decimal point is: µ33 is 0.33 µF, 3µ3 is 3.3µF and 33µ is 33µF.



3 Diodes

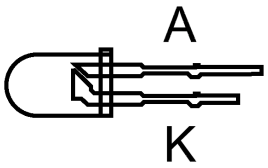
The circular band on diodes identifies the cathode (negative terminal). The bar depicts the cathode in the symbol. The positive terminal is called the anode.

Diodes are mounted horizontal. Try not to heat up the body of the diode while soldering.



4 LEDs

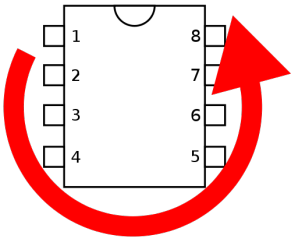
LEDs (light-emitting diodes) must be soldered with respect to the correct polarity as well. The cathode is identified by the short lead and the larger electrode inside.



5 IC-Sockets / ICs

With ICs (integrated circuits), it is essential to observe correct polarity. Most ICs will be damaged or destroyed when mounted incorrectly. The mark on the silkscreen must match the notch on top of the IC.

Pin numbers are counted **counter**-clockwise, starting from the notch.



Note: Please also pay attention to the ESD warnings at the beginning of this manual. ICs are very ESD sensitive, they can be destroyed even by a minor electrostatic discharge event!

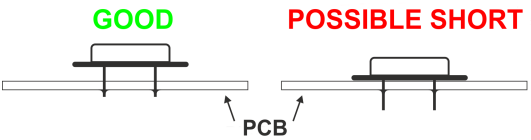
6 Transistors

Transistors must be mounted in the correct orientation. The flat side of the transistor must match the correspondent side in the silkscreen drawing. The leads may not cross.

Note: field-effect transistors (FETs) are extremely sensitive to ESD.

7 Crystal

The polarity of the crystal is not relevant, but the bottom side of the package is conductive. **To prevent shorts, the crystal should be mounted with a little distance to the board (see the image on the next page).**



8 Inductors

Inductors are soldered just like resistors. They also use similar color-coding, usually with four bands. The first two are the base value (see table below), the third is the multiplier to the base value and the fourth is the tolerance. The inductor value is:

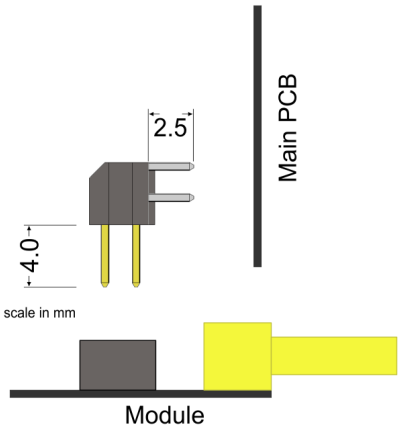
base value * multiplier [± tolerance]

Color Codes:

Color	Digit	Multiplier	Tolerance ± in %
None	-	-	20
Silver	-	10^{-2}	10
Gold	-	10^{-1}	5
Black	0	10^{0}	-
Brown	1	10^{1}	1
Red	2	10^{2}	2
Orange	3	10^{3}	-
Yellow	4	10^{4}	-
Green	5	10^{5}	0.5
Blue	6	10^{6}	-
Purple	7	10^{7}	-
Grey	8	10^{8}	-
White	9	10^{9}	-

9 Module Pin Headers

The orientation of the pin headers is as follows:



10 Crystal oscillator / TCXO Module

Unlike crystals, oscillators are polar. Pin 1 is identified by the pointy edge, the other edges are rounded.

The TCXO Oscillator Module has the same size and pinout as a standard oscillator, with Pin 1 as the pointy edge.

If the oscillator is mounted incorrectly, it will cause a short that may damage the device permanently! Please double-check the correct orientation. This also applies to the TCXO Oscillator Module. It will be destroyed if mounted with the wrong orientation!

Assembly

General note

It is essential to work precisely and systematically to minimize the possibility of faults. Check every step, each component placement and orientation, and any solder joint. Follow the assembly order given in the manual.

Take your time - it takes longer to troubleshoot than to prevent faults by working accurately.

The most common reason for a malfunctioning device is wrong component placement: either the component being placed in the wrong place or back to front. Check resistors with a multimeter if you have difficulties reading the color bands.

A common mistake is regarding capacitor labeling, such as n10 = 0.10 nF = 100 pF as opposed to 10 nF. Also, check if all leads of an IC are correctly inserted into the socket. They tend to bend during insertion.

After soldering, inspect the board for what are called cold and dry solder joints. Cold joints occur if the soldering temperature did not exceed the solder's liquidus temperature, or if the flux evaporated before it was applied on the surfaces being soldered. This is usually the result of the soldering iron being used to heat the solder directly, rather than the parts themselves. Dry joints occur when the cooling solder is moved. They often occur because the joint moves when the soldering iron is removed from the joint. When using lead solder, the joint should be smooth, bright and shiny. The joint should be reworked if it is not.

Mounting

1. Solder all of the parts without an asterisk on the side of the board where the silkscreen is. (see the picture on the next page). Wait to insert IC1 in the socket until you have finished the assembly. After all the parts on this side are soldered, please examine the board carefully for shorts, bad solder joints and correct placement. **The LCD will cover them, so you will need to desolder it to fix errors, which takes extra time and effort.** See the previous page for more information.
2. Solder the parts with an asterisk (the LCD, the Alps potentiometer, the BNC and USB connectors, and the tact switches) on the opposite side.
3. Attach the LCD:
   a) Insert the header into the board.
   b) Put the LCD on top of the header.
   c) Fix the LCD in place with the M2.5 screws and spacer bolts.
   d) Solder the header to the board and LCD. See the picture on next page for how it should look like when finished.
4. Insert IC1 into the socket. The notch on the chip must correspond with the silkscreen marking.

Installation of the modules

Channel B / PWR (Power Meter)

The modules are fully assembled and tested, they just have to be put on the appropriate pin header. The position of the socket is such that each module only fits on the correct header. Be careful not to put the module a row or column aside on the header - it may be damaged if the power is turned on then!

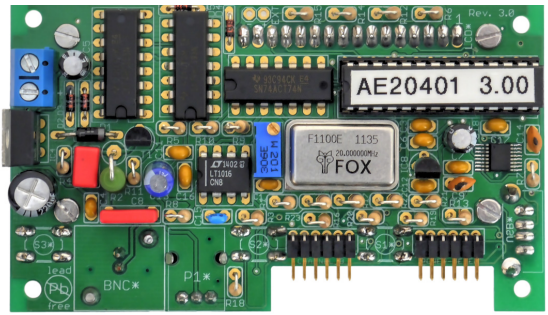
The modules may be used with a case only!

If the original optional case is not used, the unit must be enclosed in another suitable case. The SMA input jacks must be tightly screwed to the front panel with the two provided nuts, before any cables may be connected! The pin header and socket must not be exposed to mechanical stress.

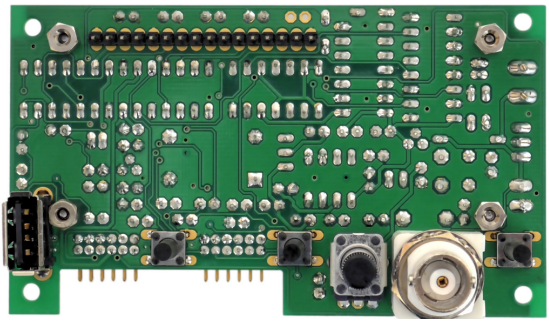
1ppm TCXO Oscillator Module

The oscillator module is soldered in instead of the standard crystal oscillator, its size and pinout is identical.

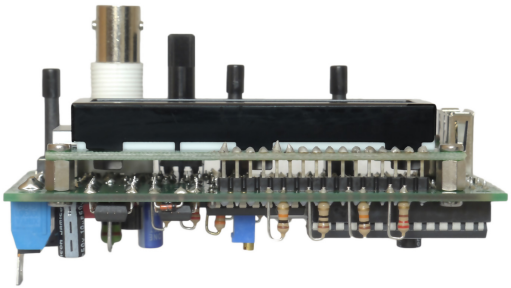
Finished Component Side



Finished Solder Side, without the LCD



LCD Mounting



Adjustment of the input amplifier

The Channel A/C input amplifier must be adjusted after the mounting is complete. The maximum sensitivity of the channel depends on an accurate adjustment. Please let the counter warm up for at least 30 minutes before performing the adjusting procedure!

Required equipment:

A signal source that produces a sine wave between 10 kHz and 1 MHz with an amplitude of about 100 mVpp is ideal.

One of the following:

a) An oscilloscope with a x10 probe. If the probe is switchable between x1/x10, select x10. x1 probes are not suitable for this procedure!

b) Multimeter.

The oscilloscope is preferred, as it gives a more accurate result.

Procedure with an oscilloscope

Set the coupling to DC on the oscilloscope.

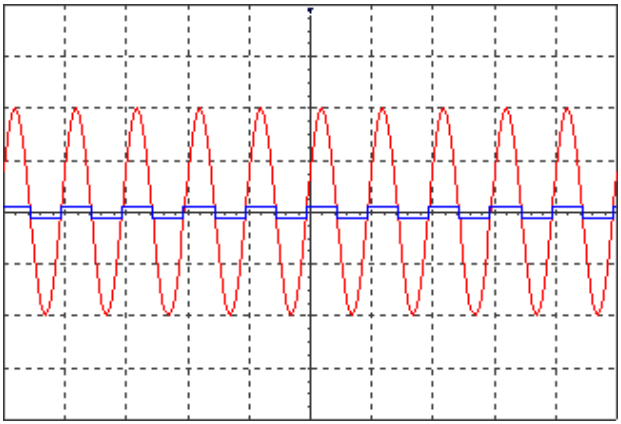
It is recommended to turn on the 20 MHz bandwidth limit or the RF reject (sometimes also called Noise Reject) if available – it will show less noise on the signal and make the adjustment easier. On digital oscilloscopes, Average mode should be enabled.

Connect the signal source to Channel A.

Probe pin 3 of IC6. You should see the input signal with reduced amplitude (shown in red in the picture on next page).

Use the vertical adjustment control on the oscilloscope to adjust the signal until it is centered on the base line as shown in the picture.

Without changing the vertical adjustment control, probe pin 2. You should see a small amplitude square wave as shown in blue in the picture. Adjust the vertical position of this signal using trim pot P2 so that the signal is also centered on the base line as shown. This completes the adjustment.



ideal adjustment

Procedure with a multimeter

The input of Channel A must be shorted (a 50Ω BNC terminator is also suitable). With the multimeter set to measure DC volts, measure the voltage between pin 2 and 3 of IC6 (**plus** on pin 2, **minus** on pin 3). Adjust trim pot P2 until a value of about 10mV is shown.

This completes the adjustment.

Troubleshooting Checklist

Check and tick off every step.

- □ Is the polarity of the supply voltage correct?
- □ Is the supply voltage in the range of 8-12V when the device is turned on?
- □ Are all resistors placed right? Check the color bands.
- □ Are the polarities of the diodes correct? The cathode band must match the bar on the silkscreen symbol.
- □ Verify the polarity of the electrolytic capacitors. Keep in mind that the marking on the capacitor can point to the (+) or (-) lead. The actual meaning is printed inside the marking.
- □ Are all ICs in the right place and with correct orientation?
- □ Are all IC leads plugged inside the socket? They can bend and stay outside easily.
- □ Measure the resistance between the power supply input terminals and between the regulated 5V rail and ground - they must not be shorted.

- □ Are there solder bridges on the solder side of the PCB causing shorts? They are easier to find if you hold the PCB toward bright light.
- □ Are there bad/cold/dry solder joints? Jiggle component leads at the solder joint with a pair of tweezers. Re-solder them if any move. If a solder joint looks suspicious, better rework it just in case.
- □ Look if you missed a soldering point. With the USB model, all pads are used.

Power Supply

An 8V-12V DC power supply capable of providing at least 300mA is required. The optional AC adapter, batteries or any other supply that meets these criteria can be used.

Warning: An AC power supply may not be used!

Note: It is advisable to use a current limiting lab power supply when switching on for the first time. Set it to 9V and 300mA, this will help to prevent damage from potential shorts.

Please pay attention to the correct polarity of the power connection! The polarity is printed on the silkscreen of the PCB.

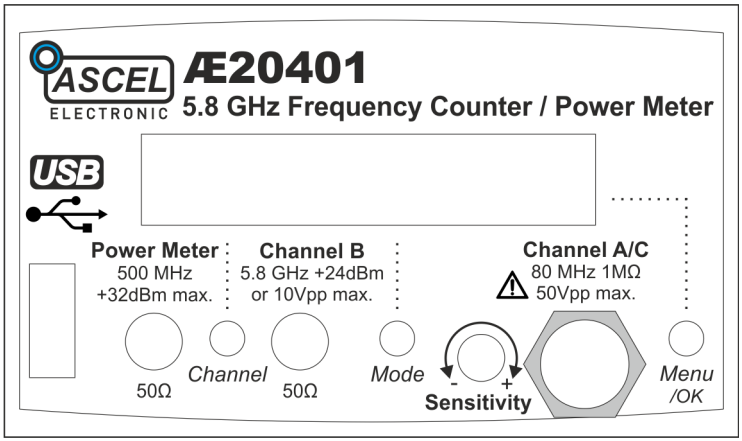
Case Mounting

Note: This describes the optional case available with the kit.

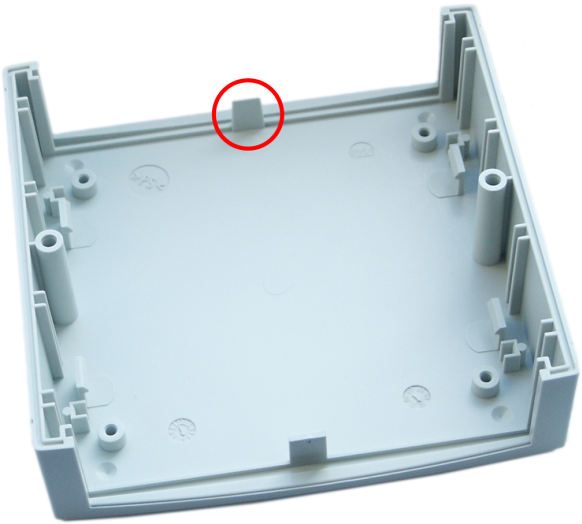
The case is provided with all necessary cutouts and labels.

1. Put the extension caps on the tact switches.
2. Join the front panel and the PCB and insert both in the respective brackets. The PCB fits in the brackets behind the front panel.
3. Install and **lightly** tighten the lock nut of the BNC connector.

   The lock nut of the BNC connector must be mounted in the orientation shown below, or it will prevent the case from closing properly.



4. The highlighted bracket on the front side of the bottom case part should be broken off, as it will interfere with the optional modules.

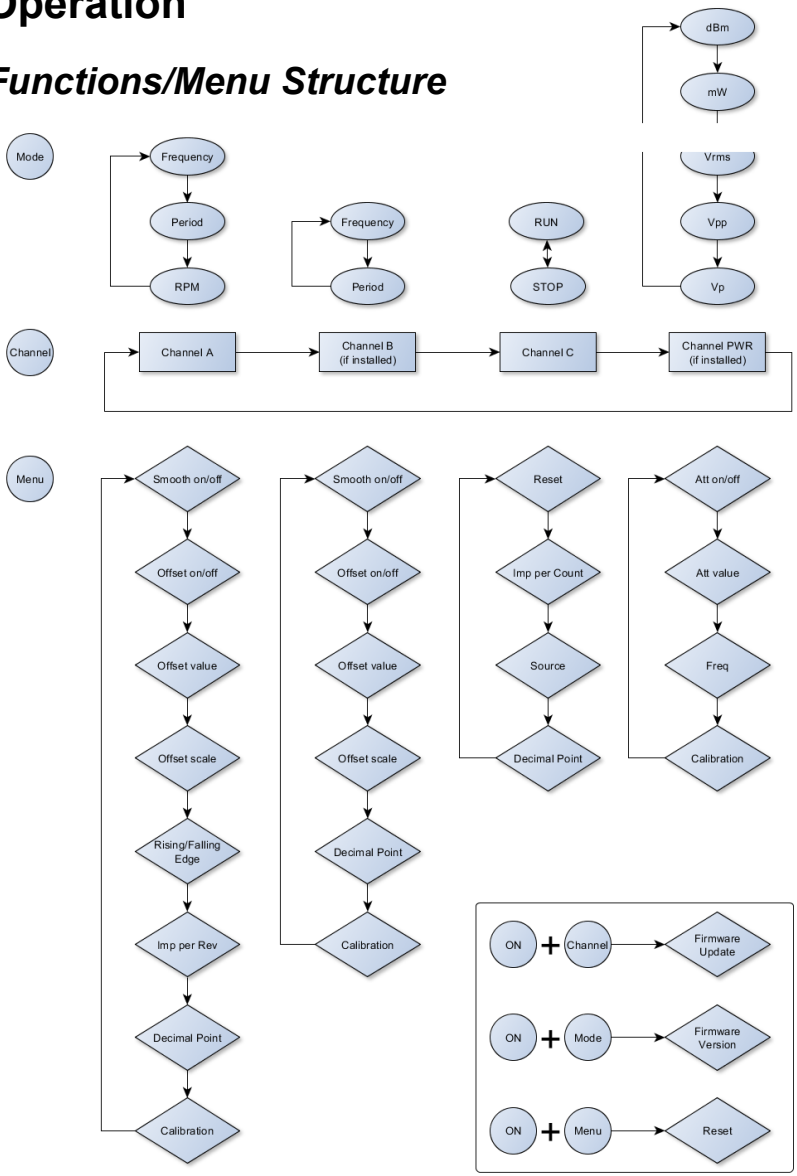


5. Solder four pieces of wire, about 15cm (6") long, to the Cinch connector and its ground leads.
6. Put the connector's wires through the appropriate hole in the back plate.
7. Attach the ground lead and solder the wires to the PCB.
8. Fasten the case with the included screws.

This completes the case mounting.

Operation

Functions/Menu Structure



General Notes

Signals may only be connected to one of the inputs or the EXT jack if the device is powered on! If a signal is applied and the device is off, damage to the input circuitry may occur, even if the signal is within the allowed limits for the particular input! Always disconnect all cables before switching the counter off.

Do not exceed the allowed maximum input voltage/power! Doing so will damage the input circuitry!

If no signal is connected to Channel A (also Channel B with high electric field strength), still a frequency may be indicated. This is not a fault, but the result of the inputs high sensitivity and the relatively high input impedance of 1 MΩ. Electric fields from the mains (50/60 Hz), WLAN, cordless phones et al. induce a voltage to the input, which is then amplified and counted. It is the same effect that let a digital multimeter with 10 MΩ input impedance always show a small voltage, when not connected to any source - here you can see the frequency of this voltage instead.

Ensure that the test leads used are suitable for the particular frequency. Correct measurements in the GHz range require all involved components (test leads, adapters, attenuators...) to be suitable for the test frequency. E.g., the widely used RG58 coaxial cable is not suitable for high frequencies!

Power-on

After the counter is switched on, it displays the installed modules. If an installed module is not shown, turn it off and check if the module is installed correctly.

Display after power-on: installed modules

Channel select

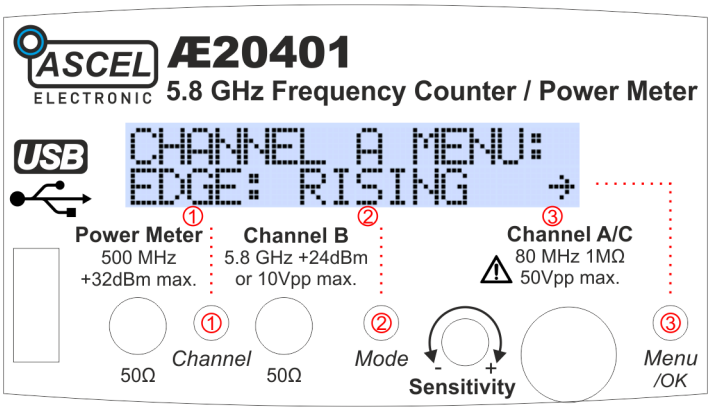
Press **Channel** to change to the next Channel. Channel B and PWR (Power Meter) are only available if the appropriate module is installed.

Mode select

To change to the next function (e.g. Frequency, Period, RPM with Channel A) or display mode (in dBm, Vrms, mW... with the Power Meter) press **Mode**. With Channel C (Pulse Counter), this starts or stops the counting (RUN/STOP mode).

Menu

To access the menu of each channel, press **Menu/OK**. Then press **Channel** to switch between the menu items and **Mode** to change the value of the selected menu items (some items leads to a submenu where a number can be entered or a function executed). The dotted line underneath the LCD shows which button corresponds with the item/value displayed on each position. The **[→]** indicates that there is a submenu or function that can be started (e.g. the calibration).



In this example, Trigger Edge is the selected item in Channel A menu (1) and **RISING** the selected value. Press **Channel** to advance to the next item or **Mode** to switch between the possible values: **RISING** and **FALLING** (2). Press **Menu/OK** to save changes and leave the menu (3).

Entering numbers

In some menus, a number must be entered, e.g. Offset Value or IMP/REV. The number is entered one digit after another, the active digit is blinking. Press **Channel** to advance to the next digit and **Mode** to increase the active digit by 1. "0" follows after "9". To help enter the whole number at once, there is no overflow - if "00090" is the number and the "9" the active digit, pressing **Mode** results in a value of "00000". If the value can become negative, the sign can be changed by pressing **Mode**.

Press **Menu/OK** to save the number and leave the menu.

"New Measurement Available" Indicator

Every time a new value is available and displayed, the "New Measurement Available" indicator dot flashes for a short time. When Channel C (Pulse Counter) is active however, the indicator is slowly blinking while the counter is active (RUN mode).

Channel A

Sensitivity adjustment

Channel A (and thereby also Channel C, as it shares the same input) has an adjustment control which allows lowering the input's sensitivity.

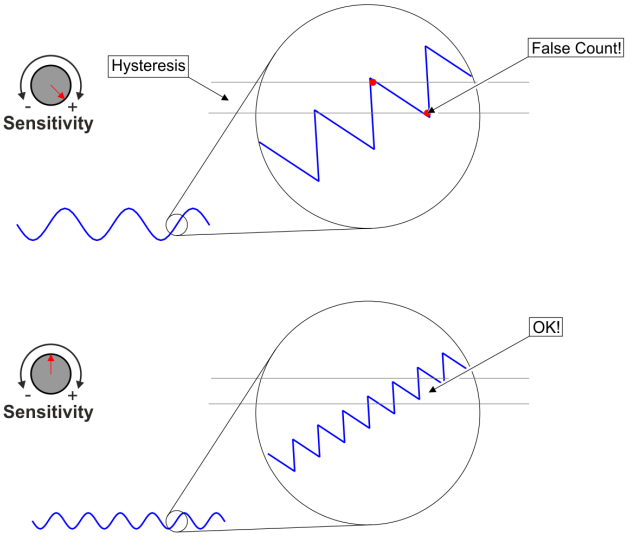
This may be necessary if the input signal is noisy or is superimposed by another signal that has a greater amplitude than the sensitivity of the input.

The input has a hysteresis of about 10 mV, so noise lower than this has no effect. However, increased immunity to noise always lowers the sensitivity for small useful signals, so a compromise has to be made here. In addition, it is required that the adjustment of the input amplifier has been done accurately (see the appropriate chapter for details).

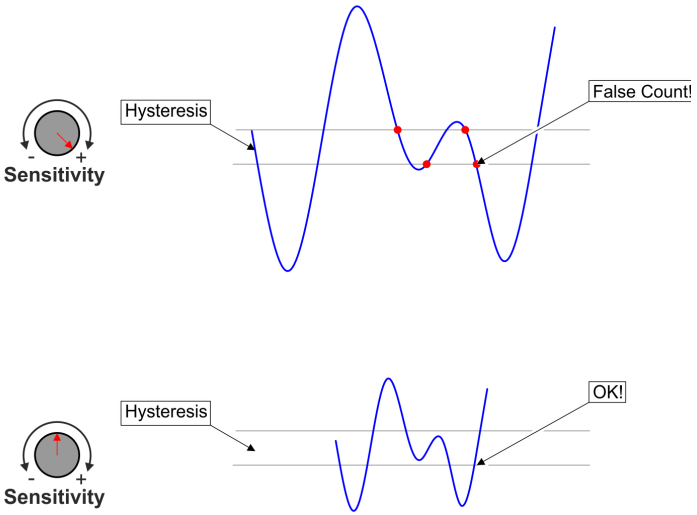
In the first example on the next page, the superimposed sawtooth wave would lead to false counts, if the sensitivity were set to max, since its amplitude is greater than the hysteresis.

If the sensitivity is lowered, this signal is below the threshold and ignored, while the sine wave is measured.

The second example shows the same behavior with one signal superimposed on another, when only the fundamental should be measured.

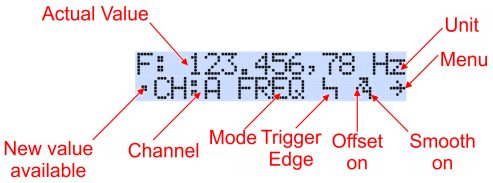


Example 1: noise



Example 2: one signal superimposed on another

Display Annunciators



Modes

The available modes are Frequency (**FREQ** $[f]$), Period (**PER** $[T]$) where: $T=\frac{1}{f}$ and Revolutions Per Minute (**RPM** $[RPM]$), where: $RPM=\frac{f}{Ip}*60$, Ip is the adjustable number of pulses per revolution.

Menu Functions

Smooth [on/off] *active in mode: FREQ, PER*

The smooth function provides a means of "smoothing" the display for easier reading of unstable values. When it is on, the counter displays a moving average of the four last measurements. A small 4 in the display indicates that Smooth is on.

Offset(/Scale) **[on/off]** *active in mode: FREQ*

The Offset/Scale function provides a means of multiplying the measured value by an entered scaling factor and then adds or subtracts another entered value. The result is then displayed:

$$f_{display} = (f * SCALE) + VALUE$$

To use the Offset/Scale function, activate this menu item and enter the values for SCALE and VALUE in the next menu items. A small arrow in the display indicates that Offset/Scale is on.

Offset VALUE

Here the VALUE for the Offset/Scale function can be entered. Positive and negative values are allowed.

Offset SCALE

Here the SCALE for the Offset/Scale function can be entered. Values below 1 can be entered for a division.

Trigger **EDGE [rising/falling]** *active in mode: all*

This menu item allows selecting whether to trigger on the rising or falling edge of the input signal. The actual setting is indicated in the display with the appropriate symbol.

IMP/REV *active in mode: RPM*

This adjustment allows selecting the number of pulses per one revolution, it is then used to calculate RPM. With this, the rpm output of rotary encoders/sensors that outputs multiple pulses per revolution can be measured.

D(ecimal) **Point ["." / ","]** *active in mode: all*

The number format (decimal point and thousands separator) can be selected between the format: "123.123.123,123 Hz" or "123,123,123.123 Hz" to match the use of different symbols worldwide.

Note: this adjustment is accessible from all channel's menus, but the same value is stored for all channels. The PC software also uses the selected format for its display.

T(ime)**base CAL**(ibration)

Starts the calibration routine for the time base. See the appropriate chapter on how to perform the calibration.

Note: the same routine is used for channels A and B, as they share the same time base.

Channel B

The operation of Channel B is virtually identical to Channel A. Please pay attention to the maximum input voltage!

Modes

The available modes are Frequency (**FREQ** $[f]$) and Period (**PER** $[T]$) where: $T=\frac{1}{f}$.

Menu Functions

Smooth [on/off] *active in mode: FREQ, PER*

Identical to Channel A

Offset(/Scale) **[on/off]** *active in mode: FREQ*

Identical to Channel A

Offset VALUE

Identical to Channel A

Offset SCALE

Identical to Channel A

D(ecimal) **Point ["." / ","]**

Identical to Channel A

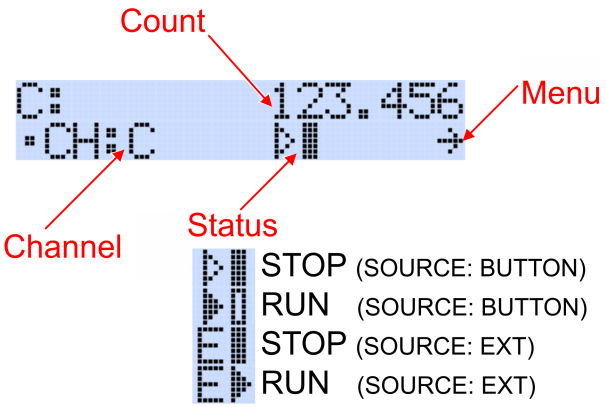
T(ime)**base CAL**(ibration)

Identical to Channel A

Channel C (Pulse Counter)

Selecting Channel C allows using Channel A as a pulse counter, instead of measuring the frequency. Start/Stop of the counter can be controlled on the device itself (SOURCE: BUTTON), using the external input jack (SOURCE: EXT) and also through USB.

Display Annunciators



If SOURCE: BUTTON is selected, pressing **Mode** starts or stops the counter. The display shows the actual status. If SOURCE: EXT, a (TTL) pulse on the EXT input starts or stops the counting.

Menu Functions

RESET

Reset the counter value back to zero.

IMP/COUNT

The number of pulses that are recognized as one "count" can be adjusted. E.g. if a moving part hits the limit switches 2x per movement and the number of movements should be counted, set IMP/COUNT to 2, the counter will count up every 2 pulses.

SOURCE [BUTTON/EXT]

The source of control can be selected between the **Mode** key and the external input.

Note: it is always possible to control via USB, no matter what is selected here.

D(ecimal) **Point ["." / ","]**

Identical to Channel A

Channel PWR (Power Meter)

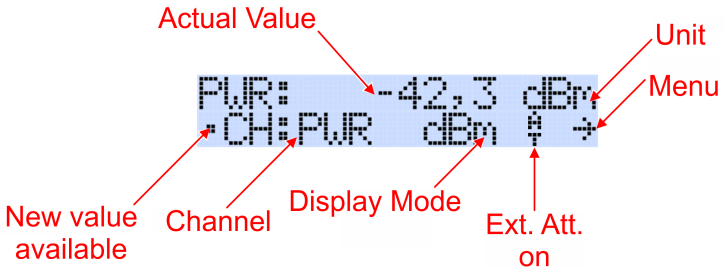
The Channel PWR Module turns the AE20401 into a Power Meter capable of measuring the power of signals from DC to 500 MHz in the range of -55 dBm to +30 dBm. This range may be further extended with external attenuators whose value can be entered and included in the displayed measurement.

Instead of the modes on Channel A and B, pressing **Mode** changes the display from dBm to mW, Vrms, Vp or Vpp. The relationship between the units is as follows:

$$P_{mW} = 10^{\left(\frac{P_{dBm}}{10}\right)} \qquad V_{rms} = \sqrt{\left(\frac{P_{mW} * 50}{1000}\right)} \qquad V_p = V_{rms} * \sqrt{2} \qquad V_{pp} = V_p * 2$$

Please pay close attention not to exceed the maximum input power! Even short overloads may cause damage to the input!

Display Annunciators



Menu Functions

EXT(ernal) **ATT**(enuator) **[on/off]**

Set this to on, if an external attenuator is connected, and enter its value in the next menu item. This value will then be added to the measurement. A small $\frac{A}{T}$ indicates that this function is on.

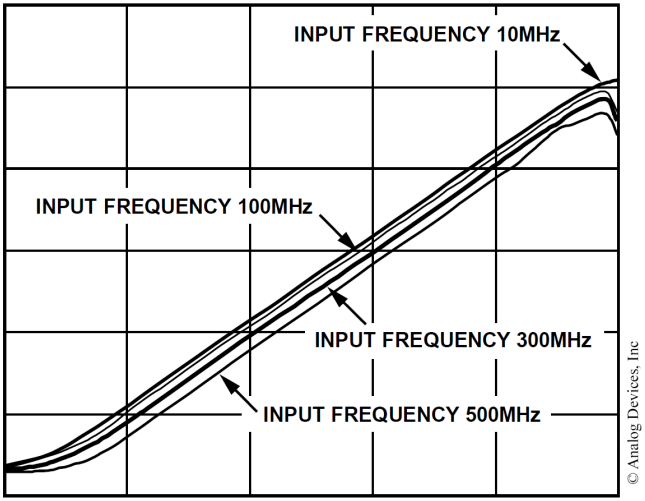
EXT ATT [VALUE]

The value of the external attenuator can be entered here in dB.

FREQ(uency) **[1/100/200/300/400/500 MHz]**

The logarithmic amplifier AD8307 which is used in this module has a slight frequency dependence. (see the graph on next page) A correction factor that compensates for the frequency error can be applied to the measurement by entering the frequency here (in 100 MHz steps).

Note: these correction factors can be adjusted by performing the full calibration procedure for the Power Meter - see the appropriate chapter about the calibration.



frequency dependence AD8307

D(ecimal) **Point ["." / ","]**

Identical to Channel A

PWR CAL(ibration)

Starts the Power Meter calibration routine. See the appropriate chapter on how to perform the calibration.

Calibration

By performing the calibration routine using precise standards, the accuracy of the time base and the Power Meter can be increased further. **Please let the counter warm up for at least 30 min before performing the calibration!**

Time Base (Channel A/B)

The calibration of the time base can be done in two ways: manually by entering an offset value in ppm (parts per million) or automatically with a precise 10 MHz reference. After the calibration routine is activated, "CAL. SELECT" is shown.

Manual Offset

Press **Channel**. Input the offset value. The value is entered in 0.1 ppm increments. Positive and negative values are accepted. With a 10 MHz input signal, +0.1 ppm causes a change of 1 Hz. Press **Menu/OK** to save and leave the calibration routine.

Automatic Calibration with 10 MHz Reference

Press **Mode.** The display will show "CONNECT 10MHz > A". Connect the 10 MHz reference signal to Channel A and press **Menu/OK**. During calibration, "CALIBRATION..." is shown. If no valid signal was recognized, "CAL ERROR, VALUE NOT SAVED!" will be shown, otherwise "CALIBRATION DONE VALUES

SAVED". Press **Menu/OK** to leave the calibration routine.

Note: there is only one calibration value, so performing automatic calibration overwrites a manually entered offset value.

Power Meter

A precise signal source is required that allows accurate adjustment of power and frequency to calibrate the power meter.

The calibration routine consists of two parts: the absolute values, and the frequency correction factors used by the **FREQ** menu setting.

The calibration starts by displaying "CONNECT -20dBm". Connect a 1 MHz, -20 dBm signal and press **Menu/OK**. During calibration, "CALIBRATION..." is shown. Next, "CONNECT +10dBm" is shown, change the signal to 1 MHz, +10 dBm. If no valid signal was recognized or the signal is outside of the max limits for calibration, "CAL ERROR, VALUE NOT SAVED!" will be shown, otherwise "CALIBRATION DONE VALUES SAVED". Press **Menu/OK** to advance to the next part.

Now you will be required to connect a number of specific signals: "CONNECT +10dBm x MHz". Set the required values and press **Menu/OK** to advance each time. A successful calibration or an error will be shown again after the calibration is finished. Press **Menu/OK** one last time to leave the calibration routine.

Reset to Defaults

Most settings, such as Offset Value/Scale, IMP/REV or Ext. Att. Value, as well as the calibration values are saved permanently and remain available after the counter is powered off and on again. To clear all saved values and reset to defaults, press and hold **Menu/OK** while switching the counter on. "LOADING DEFAULTS" is shown and the saved values will be cleared.

Display Firmware Version

To display the firmware version, hold **Mode** while switching the counter on.

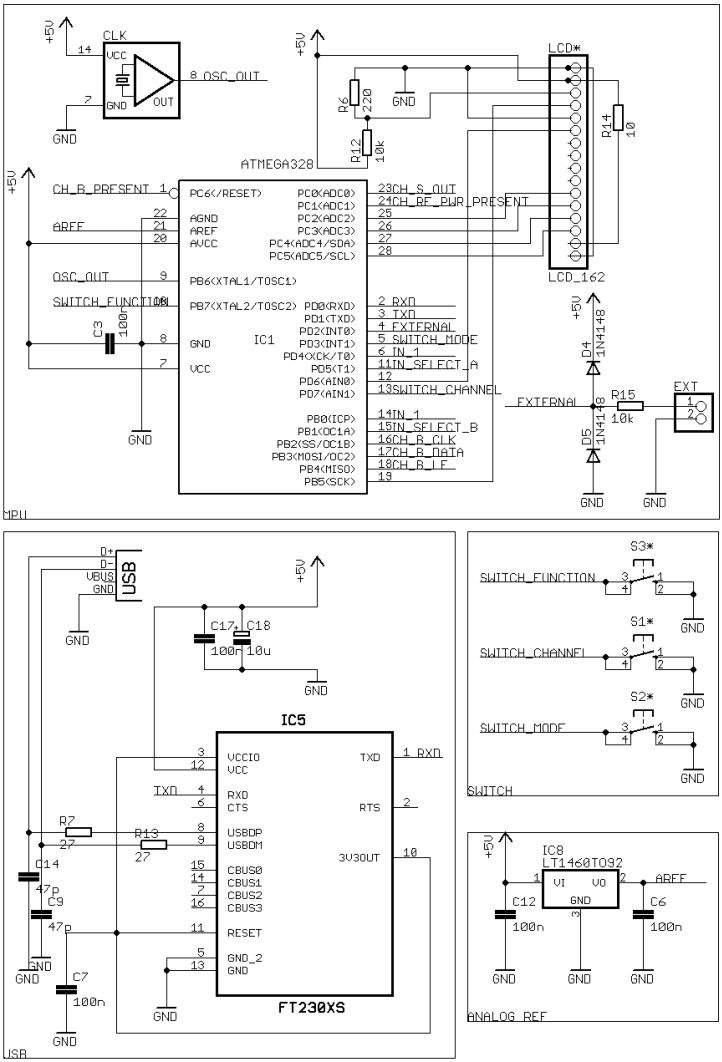
Note: The PC software also shows the firmware version.

Firmware Update

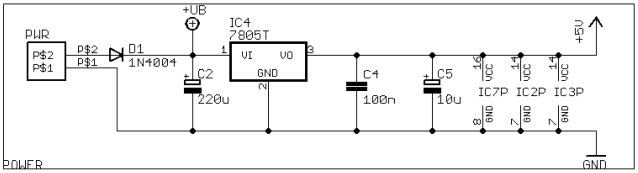
To update the firmware, hold **Channel** while switching the counter on. "FIRMWARE UPDATE" is shown. Connect the counter to a PC via USB and use the *Ascel Firmware Update Utility* to update the Firmware.

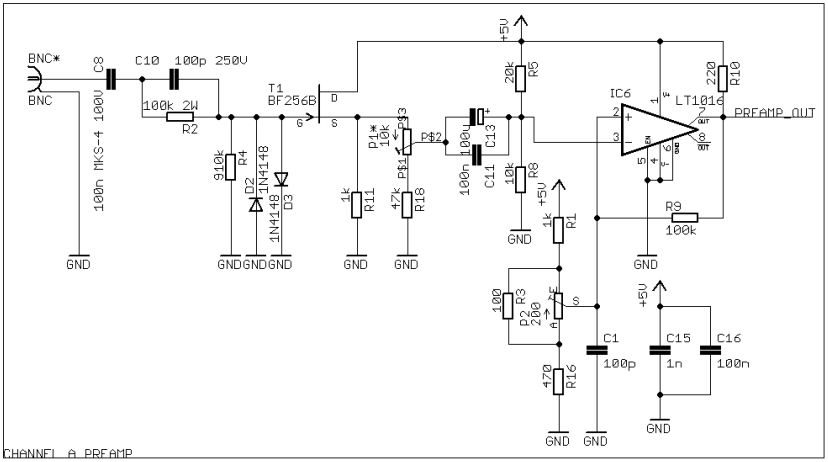
Circuit Diagram

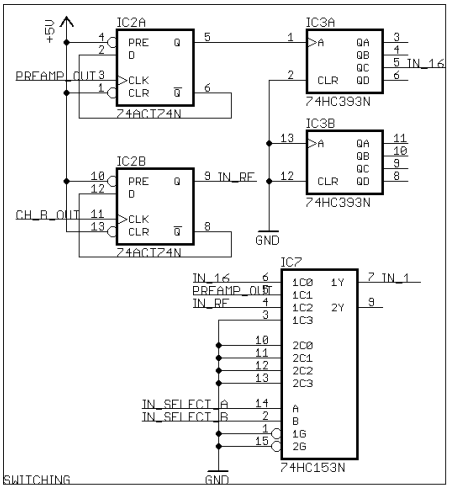
Part 1/2

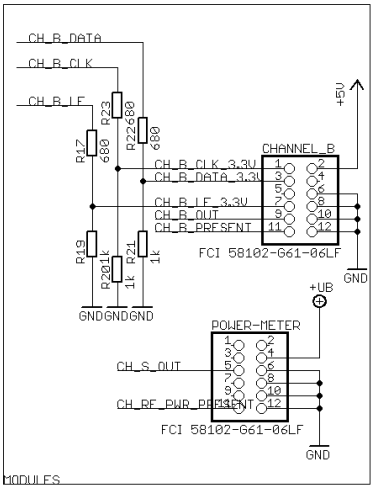


Part 2/2


+UB
PWR
P$2
P$1
D1
1N4004
IC4
7805T
VI
VO
GND
C2
220u
C4
100n
C5
10u
+5V
IC7P IC2P IC3P
POWER
GND


BNC*
BNC
C8
100n MKS-4 100V
C10 100p 250V
100k 2W
R2
T1
BF256B
D
G
S
910k
R4
D2
1N4148
D3
P1*
10k
P$3
P$4
P$2
1k
R11
47k
R18
100n
C11
100u
C13
20k
R5
10k
R8
+5V
1k
R1
IC6
LT1016
PREAMP_OUT
220
R10
R9
100k
100
R3
200
P2*
C1
100p
C15
1n
C16
100n
470
R16
GND
CHANNEL A PREAMP


+5V
IC2A
PRE
D
CLK
CLR
Q
PREAMP_OUT
74ACT74N
IC3A
IC3B
74HC393N
IN_16
IN_RF
IC2B
CH_A_OUT
IC7
1C0
1C1
1C2
1C3
2C0
2C1
2C2
2C3
1Y
2Y
A
B
1G
2G
IN_SELECT_A
IN_SELECT_B
74HC153N
GND
SWITCHING


CH_B_DATA
CH_B_CLK
CH_B_LF
R23
680
R22
680
R17
680
CHANNEL_B
CH_B_CLK_3.3V
CH_B_DATA_3.3V
CH_B_LF_3.3V
CH_B_OUT
CH_B_PRESENT
FCI 58102-G61-06LF
R19
201k
R20
1k
R21
1k
+5V
+UB
GND
POWER-METER
CH_S_OUT
CH_RF_PWR_PRESENT
FCI 58102-G61-06LF
MODULES

Bill of Materials

Quantity	Parts(s)	Value / Description
7	C3, C4, C6, C11, C12, C16,	100nF
1	C1	100pF Ceramic
1	C10	100pF Film
1	C8	100nF Film
1	C15	1nF
1	C5	10µF Electrolytic
1	C13	100µF Electrolytic
1	C2	220µF Electrolytic
5	R1, R11, R19, R20, R21	1KΩ
1	R2	100KΩ 2W
1	R3	100Ω
1	R4	910KΩ
1	R5	20KΩ
2	R6, R10	220Ω
3	R8, R12, R15	10KΩ
1	R9	330KΩ
1	R14	10Ω
1	R16	470Ω
3	R17, R22, R23	680Ω

Continued on next page

1	R18	47KΩ
1	IC1	IC Socket 28 pin / Microcontroller
1	IC2	74ACT74 Quad Flip-Flop
1	IC3	74HC393 Dual 4-bit Counter
1	IC4	7805 Voltage Regulator
1	IC6	LT1016 Comparator
1	IC7	74HC153 Multiplexer
1	IC8	LT1460 2.5V Reference
1	P1*	ALPS Potentiometer 10K
1	P2	Trimmer 200Ω
1	D1	1N4007 Diode
4	D2, D3, D4, D5	1N4148 Diode
1	T1	BF256A JFET
1	EXT	Cinch Connector
1	PWR	Power Connector
1	BNC*	BNC Connector
2	CHANNEL_B, POWER-METER	2x6 Pin header right angle
1	LCD*	2x16 Dot-Matrix LCD
3	S1*, S2*, S3*	Tact Switch
1	CLK	Crystal Oscillator 20 MHz **or** 1 ppm TCXO Oscillator Module

Continued on next page

USB Models only:

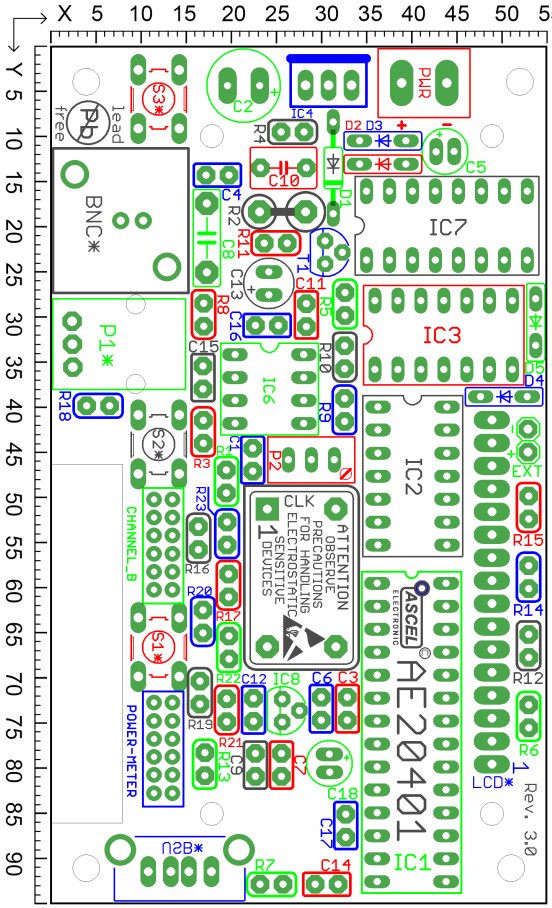
1	*IC5*	*FT230X USB UART Interface (pre-assembled)*
2	C7, C17	100nF
2	C9, C14	47pF
2	R7, R13	27Ω
1	C18	10µF Electrolytic
1	USB*	USB Type "A" Connector

Other:

- PCB
- 4 spacer bolts and 8 M2.5 screws for LCD mounting
- *Modules (optional)*
- *Case and 3 extension caps for the tact switches (optional)*
- *AC adapter (optional)*

Note: Parts whose designator contains an asterisk are mounted on the opposite side of the PCB. See "Assembly" chapter for details.

Component Placement Diagram



(X x Y)

C1 (22x46)	P1* (2x33)
C2 (21x4)	P2 (29x47)
C3 (33x73)	PWR (44x4)
C4 (19x14)	R1 (20x48)
C5 (44x12)	R2 (26x18)
C6 (30x73)	R3 (17x43)
C7 (26x80)	R4 (27x10)
C8 (17x21)	R5 (33x29)
C9 (23x80)	R6 (53x74)
C10 (26x13)	R7 (25x93)
C11 (28x30)	R8 (17x30)
C12 (22x73)	R9 (33x40)
C13 (24x26)	R10 (33x34)
C14 (31x93)	R11 (25x22)
C15 (17x37)	R12 (53x66)
C16 (24x31)	R13 (17x80)
C17 (33x86)	R14 (53x59)
C18 (31x79)	R15 (53x51)
CLK (28x59)	R16 (16x54)
D1 (31x14)	R17 (20x60)
D2 (37x13)	R18 (5x40)
D3 (37x11)	R19 (17x72)
D4 (50x39)	R20 (17x64)
D5 (54x31)	R21 (20x74)
EXT (53x44)	R22 (20x67)
IC1 (40x76)	R23 (20x54)
IC2 (40x48)	S1* (12x67)
IC3 (44x32)	S2* (12x44)
IC4 (31x4)	S3* (12x6)
IC5 (27x87)	T1 (30x23)
IC6 (24x38)	BNC* (8x19)
IC7 (44x20)	LCD* (33x48)
IC8 (26x74)	

Note: Parts whose designator contains an asterisk are mounted on the opposite side of the PCB. See the chapter "Assembly" for details.

Note: To help locate the right elements, parts and their respective designators are highlighted in the same color.

Scale in mm.

Data Interface

The AE20401 frequency counter optionally comes with an USB interface which can be used to control all of its functions and read out the measured values. The USB driver creates a virtual serial (COM) port. This makes integration with external tools and applications very easy.

System Requirements

USB Interface:

- MS Windows®[1]98/ME/2000/XP/Vista/7/8/ Server 2003/Server 2008/Server 2008 R2/ Server 2012/Server 2012 R2 x86/x64
- Mac® OS X®
- Linux

PC Software:

- MS Windows with .NET® -Framework *(at least version 4.0)*

1 *All trademarks are the property of their respective owners.*

USB Driver Installation

The driver for the virtual serial port must be installed before the software can be used. Drivers for all supported operating systems are included with the device., They can be found in the "Driver" directory on the CD.

Note: Newer Windows OS (starting with Windows 7) can install the driver automatically if an Internet connection is present.

Note: You can change the number of the COM Port assigned by Windows after the first connection is made, by going to Control Panel / Device Manager and selecting the port. Select Properties / Port Settings / Advanced and assign a new number. It will remain even after the device is disconnected and connected again later.

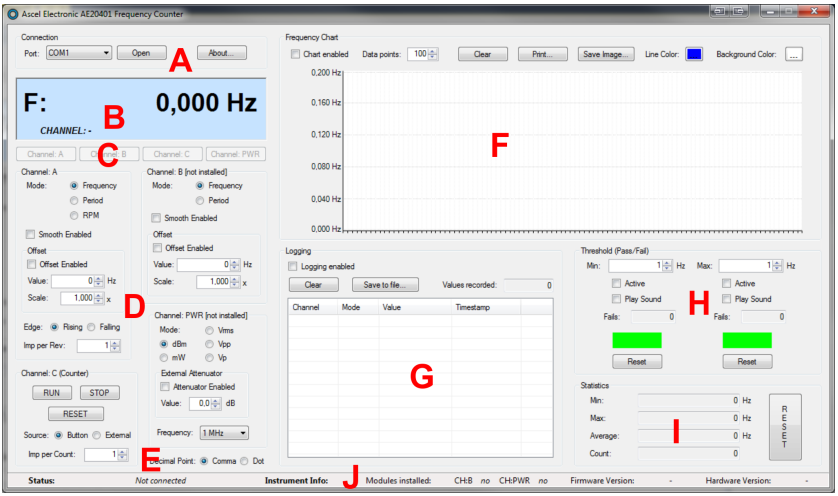
Software Installation

The PC software can be found in the "Software" directory. Execute setup.exe to install the software. There is also a portable version of the software in the "Portable Software" directory that does not require installation.

Note: The .NET-Framework (at least version 4.0) must be installed prior to the software installation.

Note: The USB driver is initialized on first connection. The software may not respond for a few seconds at this time.

Software Screenshot



Software Operation

First, select the COM port the counter is connected to **A** and click "Open". The connection will be established. The display **B** shows the values in a similar manner as the counter's display. Press one of the buttons **C** to change the channel. The controls assigned to this channel **D** will be activated, the functions are identical to direct control on the device. Use **E** to change the decimal point. The frequency can be shown as a graph **F**. The graph can be saved to a file or printed. **G** allows logging all measurements and saving them as a *.csv file. A pass/fail function is also available **H**. It will indicate if the set min/max values are exceeded. **I** shows various statistics. **J** shows information about the connected device.

Specifications

Channel A:

Frequency Range:	2 Hz - 80 MHz
Modes:	Frequency, Period, RPM
Pulse/Revolution (RPM):	adjustable
Functions:	Offset, Smooth, Trigger Edge
Sensitivity:	1 MHz: 50 mV 50 MHz: 100 mV *Sine wave, in Vrms*
Impedance:	1 MΩ
Coupling:	AC
Attenuation:	adjustable
Max. Input Voltage:	50 V (DC+ACpp)
Input:	BNC

Channel B:

Frequency Range:	70 MHz - 5.8 GHz
Modes:	Frequency, Period
Functions:	Offset, Smooth
Sensitivity:	200 MHz: 50 mV *Sine wave, in Vrms*

	1 GHz: -20 dBm 3 GHz: -15 dBm 5 GHz: -5 dBm
Impedance:	50 Ω
Coupling:	AC
Max. Input Voltage:	+24 dBm (10 Vpp)
Input:	SMA

Time Base:

Accuracy (Standard):	50 ppm
Accuracy (TCXO Option):	1 ppm
Calibratable:	yes

Channel C (Pulse Counter):

Frequency Range:	2 Hz - 5 MHz (50% duty)
Sensitivity:	identical to Channel A
Max. Value:	4.294.967.296
Pulse/Count:	adjustable
Impedance:	1 MΩ
Coupling:	AC
Attenuation:	adjustable
Max. Input Voltage:	50 V (DC+ACpp)
External Control Input:	TTL 5V

Channel PWR (Power Meter):

Frequency Range:	DC - 500 MHz
Modes:	dBm, mW, Vrms, Vp, Vpp
Functions:	External Attenuator
Impedance:	50 Ω
Range:	-55 dBm - +30 dBm
Resolution:	0.1 dBm
Calibratable:	yes
Input:	SMA

General:

Display:	2x16 dot matrix LCD
PC Interface:	USB (optional)
Supply Voltage:	8-12V DC
Power Consumption:	max. 3W
Temperature:	+5°C - +40°C
Relative Humidity:	< 85% non-condensing

Data Format

Format: <ECN>:<CODE>:<DATA>:;

<*ECN*> 401 – Device Identification Number. It is always 401 for this device.

Example: 401:F:0:; Set Channel A Mode to FREQ

Code	DIR	Function	Value (DATA)
A	→	Frequency Channel A	in nHz*
B	→	Frequency Channel B	in uHz*
C	→	Counter Channel C	in Count
D	→	Power Channel PWR	in 0.1dBm
E	↔	Current Channel	0 = A, 1 = B, 2 = C, 3 = PWR
F	↔	Channel A: Mode	0 = FREQ, 1 = PER, 2 = RPM
G	↔	Channel A: Rising/Falling Edge	0 = Rising, 1 = Falling
H	↔	Channel A: Smooth Enabled?	0 = FALSE, 1 = TRUE
I	↔	Channel A: Offset Enabled?	0 = FALSE, 1 = TRUE
J	↔	Channel A: Offset Value	in Hz
K	↔	Channel A: Offset Scale	in x0.001
L	↔	Channel A: Imp/Rev	in x1
M	↔	Channel B: Mode	0 = FREQ, 1 = PER
N	↔	Channel B: Smooth Enabled?	0 = FALSE, 1 = TRUE
O	↔	Channel B: Offset Enabled?	0 = FALSE, 1 = TRUE
P	↔	Channel B: Offset Value	in Hz
Q	↔	Channel B: Offset Scale	in x0.001
R	↔	Channel C: RUN/STOP	0 = STOP, 1 = RUN
S	↔	Channel C: Source	0 = INT, 1 = EXT
T	↔	Channel C: Imp/Count	in x1
U	↔	Channel PWR: Mode	0 = dBm, 1 = mW, 2 = Vrms, 3 = Vpp, 4 = Vp
V	↔	Channel PWR: Attenuator Enabled?	0 = FALSE, 1 = TRUE
W	↔	Channel PWR: Attenuator Value	in 0.1dB
X	↔	Channel PWR: Freq	0 = 1 MHz, 1 = 100 MHz, 2 = 200 MHz, 3 = 300 MHz, 4 = 400 MHz, 5 = 500 MHz
Y	↔	Decimal Point	0 = ',' 1 = '.'
Z	←	Channel C: Reset	
1	→	Modules Installed?	0 = none, 1 = CH:B, 2 = CH:S, 3 = both
2	→	Hardware Rev.	
3	→	Firmware Rev.	
4	→	Product ID	
5--9		*Reserved*	
0	←	Get All Settings	

PC→DEVICE send only; PC←DEVICE receive only; PC↔DEVICE send and receive
**The number of valid counts depends on range*