mino Fmeter-G431: optimized reciprocal frequency counter 0.1 Hz - 150 MHz

Technical information:

This frequency counter combines the reciprocal measuring method and the statistical evaluation of many individual measurements (linear regression) in one finished module. The circuit and program are optimized so that a wide range of applications can be covered - without special signal processing or consideration of very low frequencies. The operation can be done manually or by ser. interface (RS232). An LC display (> = 2 x 16) can be used, but is also not required if the control and measured value output is only to be carried out via RS232. Whether as a simple panel meter with a few digits of resolution, a mobile measuring device with power supply from a battery / power bank or as a high-precision, finished tabletop device with an external 10 MHz reference and supplemented signal conditioning / prescaler, the range of applications is varied.

Optimizations / compromises:

The reciprocal measurement method is particularly suitable for low input frequencies. Comparing to other mino-counters here the measuring range was limited to an input frequency > = 0.1 Hz, which is why the internal calculations manage with 32-bit variables, which accelerates the calculations during the evaluation. The highest resolution in the low frequency range through time interpolation (TDC) was omitted too. Many users do not need this, but a higher resolution at higher frequencies in the MHz range. This results from the statistical evaluation of up to 200,000 individual measurements/s.

In the hardware, the input stage is designed for simple signal forms (sinusoidal, rectangular). Since the lowest input frequencies do not have to be taken into account, a simple AC-coupled amplifier stage with a subsequent Schmitt trigger is sufficient. A separate 2:1 prescaler is part of the event counter. On the one hand, this doubles the input frequency range and, on the other hand, the 1-bit counter offers the µC input a signal with an optimal 50% duty cycle. Even short input pulses of 2 - 3 ns can be recorded.

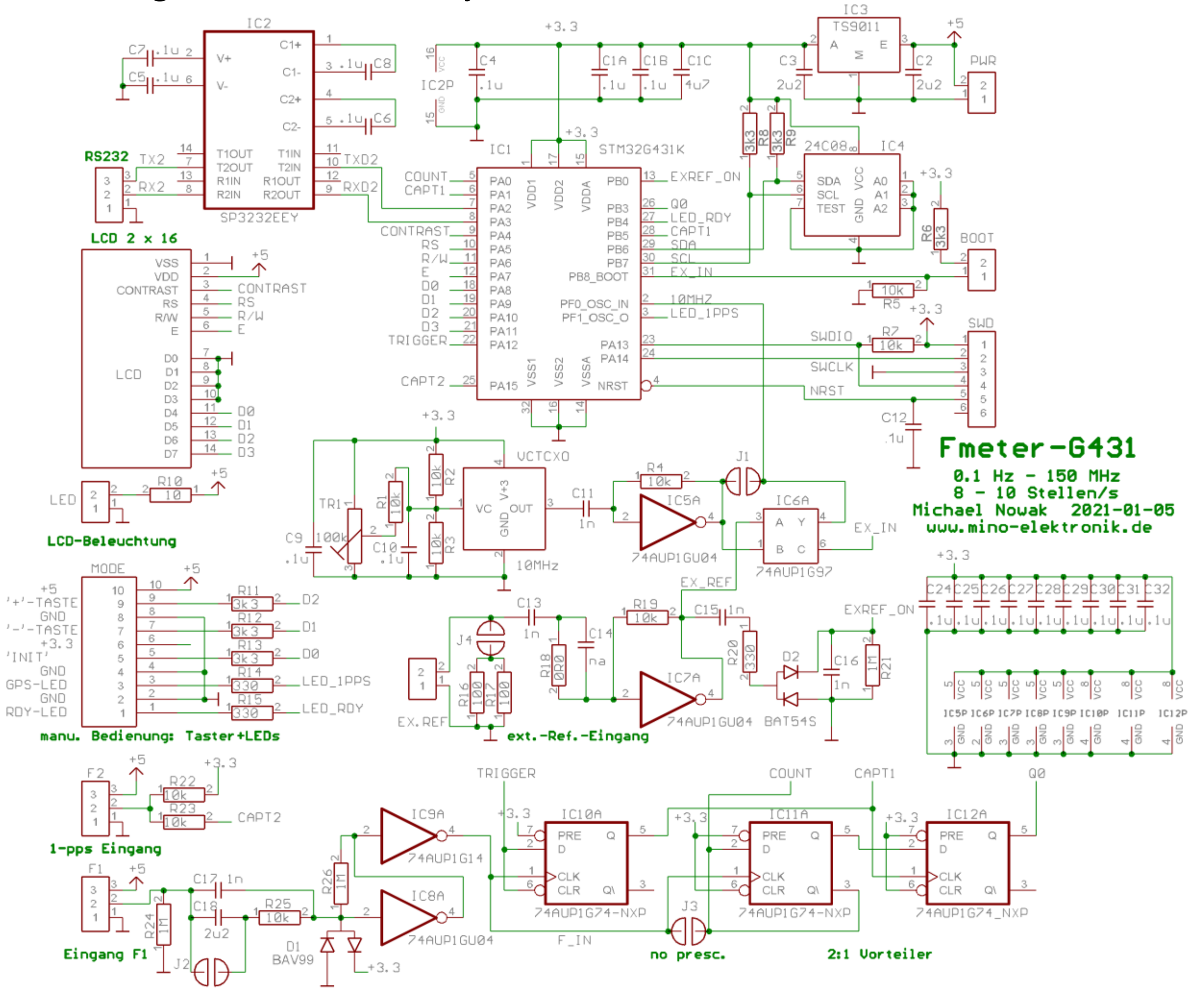
Technical specifications:

- Input F1: 0.1 Hz - 150 MHz with 8 - 11 digits result; gapless measurements
  0,1 Hz - 50 Hz @ 1 s: 8 digits
  50 Hz - 5 kHz @ 1 s: 9 digits
  >= 5 kHz @ 1 s: 10 digits
  >= 5 kHz @ 10 s: 11 digits

- Auxiliary input F2: 0.1 Hz – 5 kHz with 8 digits / s; for 1 pps GPS signal
- measuring time from 0.001 - 25.000 s in 1 ms steps
- timeout from 0.001 to 25.000 s in 1 ms steps
- showing 5 - 12 digits manually or automatically depending on eff. measuring time
- Frequency display: autom. in 'mHz' - 'GHz' or fixed format in 'MHz'
- Display formats: 1.2345 Hz; 1.2345E+0; 1,2345 Hz; 1,2345E+0
- Scaling factor for separate prescaler: 1 - 99999
- Adjustable divisor for rotation speed: 1 - 99999

- internal reference frequency (170 MHz) from local 10 MHz (VC)TCXO or ext. Reference signal 4 - 20 MHz
- automatic detection of the external or (VC)TCXO clock in 1 MHz grid
- manual or automatic comparison with 1 pps GPS signal
- Adjustment range +/- 5 ppm with 0.01 ppb resolution
- Storage of all parameters / adjustment values in the EEPROM / FRAM
- 2 x LED outputs for "Ready" and "GPS active"
- 3 x inputs for control buttons (configuration)
- Display with LCD module 2 x 16 -> 4 x 20 with presetting 16 characters / line
- RS232 connection with 9600 Bd ... 256 kBd for data output
- 5 V supply approx. 100 mA, (without LCD)
- (experimental, see below) increased input frequency 200 MHz

Circuit diagram with full assembly:



Explanations of the circuit

Input F1: The measurement signal is applied to this input. C18 separates the DC voltage component from the signal and, in conjunction with R26, determines the lower limit frequency. C17 serves as a high pass for higher frequencies. The protection diode D1 (BAV99, low capacitance) and R25 serve to protect the input of the inverter IC8, which provides a certain amount of current limitation. IC8 amplifies the input signal and provides a quiescent level of Vcc/2 (approx. 1.65 V) at the output and thus the sensible bias voltage for the following Schmitt trigger IC9, at whose output steep square-wave signals drive the

following D-FF. The flip-flop IC10 synchronizes the time measurement with the input pulses when requested by "TRIGGER"; the "CAPT1" signal saves the current counter readings (µC internal capture register for events and time).
D-FF IC11 serves as a 2:1 prescaler for event measurement and IC12 as the associated latching register for reading out the lower-order bit "Q0". The prescaler can be omitted if the solder bridge J3 is activated and this is taken into account in the evaluation program.

Input F2: This auxiliary input is preferably intended for square-wave signals (1 pps from the GPS receiver, sensors with TTL / CMOS output level). The signal amplitude should be 3.3 V. The pull-up resistor R22 (10 k) can be adapted or omitted depending on the signal source. R23 is used against simple overvoltage at the input. If this input is to be used for signals other than GPS, this input can only be used up to 5 kHz (is internally limited by the program). Currently the measured values of F2 are only shown on a 4-line display in lines 3 and 4 and, if set, are output via RS232. Contrary to the setting options for input F1, the typical measuring time at F2 is 0.666 seconds with a timeout after 5 seconds. The display has 8 digits.

Internal reference frequency: The local VCTCXO (typ. 10 MHz) supplies the basic clock for the µC. With a basic accuracy of approx. 1 ppm, this clock frequency is only suitable for lower demands with a resolution of <= 8 digits, if an adjustment is carried out regularly. If manual adjustment with the trimming potentiometer is not required, a TCXO can also be used.

External reference frequency: For high-precision measurements, an external reference signal (typ. 10 MHz) must be applied to this input, as it is provided by ext. Time bases is generated. For maximum accuracy, the rate should be more stable than 0.1 ppb (1 x 10e-10). The amplitude should be in the range 1 - 3 Vss. Sine or square wave signals are suitable as signal forms. A 50 Ohm line termination consisting of R16 || R17 can be switched on. The following CMOS inverter IC7 buffers and amplifies the input signal. The µC recognizes the external reference signal and uses it preferably before the internal (VC) TCXO clock (automatic switching with IC6).

RS232 : A result can be output via RS232 for automatic further processing of the measured values. The options are: frequency, period and speed of F1 and frequency F2. In addition, various parameters can be set via RS232, provided that manual operation is not intended or the settings are to be made remotely.

Manual operation: parallel to the LCD, three input buttons can be queried for manual operation. "RDY-LED" and "GPS-LED" are used to display the completed measurement and the steady 1 pps mean.

Adjustment:
Mechanical: If a VCTCXO and trimming potentiometer are fitted, the reference frequency can be adjusted directly. Turning it clockwise increases the displayed value. This is enough for a resolution of 7 digits.

Via software: Internal and external reference frequency are adjusted separately. The setting relates to the selected frequency (internal / external). It makes sense to choose the longest possible measuring time > = 1s for the adjustment. So that the last digit can still be fine-tuned in a 10-digit measurement, the graduation of the associated offset is 0.01 ppb (1 x 10e-11). A frequency displayed that is too low is corrected with a positive offset (.nnnnO) and a frequency that is too high with a negative offset (.-nnnnO). "nnnn" is a relative value to the value already set. This simplifies the fine adjustment. Only the entry of .0O sets the set offset to 0.

Example: the input signal at F1 is exactly 10.00000000 MHz and an OCXO serves as an external clock generator. The displayed value is 9.999999989 MHz. You can see that the displayed value is ___11 too low. In the 10-digit display, the last digit provides a resolution of 0.1 ppb. Since the correction value (offset) has a higher resolution of 10, it must be entered with 110. Input: .110O Then check the displayed value again and correct it if necessary, which can be done with small steps of, for example, 5: .5O to increase or. -5O to decrease the offset. The alignment is perfect when "10.00000000 MHz" and "100.0000000 ns" are displayed at the same time.

For the first time, the settings are only temporarily stored in the RAM, so that the last setting is not initially 'destroyed'. In order to use this value again the next time it is switched on, it must be written into the EEPROM after the adjustment has been completed with ' . < Strg-S>' or '. <Ctrl-S>'.

Experimental increase in the input frequency:

The maximum input frequency depends directly on the clock frequency of the µC-internal timer. If the max. measuring range of 150 MHz is not sufficient, it can optionally be increased to approx. 200 MHz. The internal clock frequency is increased from 170 MHz to 240 MHz, which is outside the specification, but can be helpful if it works.

To activate, a resistor of 3.3 kOhm is connected between the LCD lines RS (pin 4) and R/W (pin 5). This is checked once for presence when it is switched on and the increased clock frequency is used if necessary. Due to the higher clock frequency, the current consumption increases by approx. 10 mA, which does not lead to excessive heating of the µC. If this is not required, leave it at the basic setting.