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# VTF

## VOLTAGE (AND TEMPERATURE) TO FREQUENCY CONVERTER

Ver 990414-d1

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### **1. INTRODUCTION**

This paper outlines a Voltage To Frequency<sup>1</sup> Converter Sensor (VTFCS) for use with the METCON telemetry and control system. This sensor measures an external positive voltage and then frequency modulates an external circuit for remote monitoring. It also includes an optional temperature sensor.

### **2. WHY CONVERT TO FREQUENCY?**

A good question would be "if you want to measure voltage why convert it to frequency?". One advantage of VTF is that the signal to be measured can be converted to a frequency right at the source. The audio frequency signal (0 to 10 kHz) can then be transmitted over wires (or radio for that matter) to the monitoring unit where the frequency of the audio signal is measured and stored in memory for remote access. Additionally, the signal can be passed through a simple opto-isolator to provide a large voltage isolation capability between the signal source and the monitoring unit. The audio signal can be transmitted over telephone house wires as a 5 volt peak-to-peak digital signal. There could be up to 0.5 VACrms of 60 Hz hum on this line but the "digital" audio frequency signal will still be received with the correct frequency. Also, it's unlikely that external noise induced into the wires would convert a 2360 Hz signal to 2130 Hz.

However, the analogous situation for Analog-to-Digital Conversion doesn't fair so well. What might be the chance of transmitting a 0.236 VDC signal down a 500 foot run of telephone wire and having a digital voltmeter at the other end reading 0.236 volts? Probably not good; especially when the air conditions compressor motor starts up, or the refrigerator starts up, or ... well you get the idea. The down-side of VTF is that each update take some time to acquire (one second for each channel in the case of METCON-1).

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<sup>1</sup> VTFC stands for "Voltage-To-Frequency Converter" and implies the concept of voltage to frequency conversion. VTFCS stands for this particular VTFC Sensor design or system.

### **3. VTF FUNCTIONS**

This sensor measures an external positive voltages in one of two ranges with an input impedance of 1 M ohms or more. The output consists of an opto-isolator transistor that can amplitude modulate an external current source at a frequency proportional to the voltage being measured by VTF-1. When configured for the HIGH voltage range VTF-1 can accept input signals in the range of 0 to 100 volts and the conversion gain is 100 Hz per volt. When configured for the LOW voltage range VTF-1 can accept input signals in the range of 0 to 10 volts and the conversion gain is 1000 Hz per volt.

VTF-1 can also be configured to measure temperature in Fahrenheit or Celsius, positive only or positive and negative. This is accomplished by installing a temperature sensor and an offset reference circuit (if negative temperatures are expected).

### **4. CIRCUIT DESCRIPTION.**

When configured for 0 to 10 volt inputs, P1 is shorted while P2 and P3 are open. R1, R2 and R3 form a voltage divider that reduces the input signal to either 80% or 8% of its original value. The use of 80% (or 8%) limits the voltage at the input of IC1 to 8 volts, maximum. IC1 will operate correctly provided that the input remains at least 2 volts below the power supply voltage. For VTF-1, with a maximum input voltage of 8 volts the power supply can be as low as 10 volts, or 10.7 volts at pins 1 and 2 of J1 (accounting for the voltage drop across D1). When configured for 0 to 100 volt inputs, P2 is shorted while P1 and P3 are open. C1 provides a compensating capacitor to smooth the signal and form a time constant similar to the integrating capacitor C2.

IC1 is the voltage to frequency converter<sup>2</sup>. Current pulses are generated by the IC and appear on pin 1 which are then integrated by C2. R4 discharges C2 when current is not being supplied by pin 2. R5 provides a hysteresis effect that improves linearity. R6 and R7 are used to adjust the conversion gain of IC1 and associated components by determining the amount of current output on 1 pin. R8 and C3 determine the length of the current pulses that are output on pin 1. When P4 is shorted so that R17 is now in parallel with R8 the gain of IC1 is increased by a factor of 10. This is useful when measuring very low voltages such as those from the temperature sensor.

R9 pulls up the open collector frequency output of IC1. Typically, the output of IC1 consists of narrow pulses that are not suitable for transmission over long cable runs. IC2A is a D-flip-flop that's configured as a divide by two element. the signal at the output of IC2A pin 1 is a 50% duty cycle signal that can easily travel over twisted pair cable to the monitoring unit. IC2B is configured as an inverter and is used to drive Q1. R10 can be lowered in value, if needed, to drive Q1 harder without loading IC2A. IC3, an opto-isolator, is used to provide isolation between VTF-1 and the monitoring unit.

VTF-1 requires 11 to 15 volts DC for proper operation. The ground of the power source must be common with the signal to be measured. However, there doesn't need to be any common or reference connection between VTF-1 and the monitoring unit.

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<sup>2</sup> See the National Semiconductor Data Acquisition Linear Devices Databook for an excellent discussion of how this chip operates.

## **5. CALIBRATION**

VTF-1 may be configured for either HIGH voltage range inputs (0-100), LOW voltage range inputs (0-10), or temperature. The sections below discuss the different calibration procedures for the different configurations.

### **5.1 VOLTAGE CALIBRATION**

Configure VTF-1 for either the HIGH or LOW voltage range. For HIGH, install a shorting plug at P2 and ensure that no shorting plugs are installed at P1 or P3. For LOW, install a shorting plug at P1 and ensure that no shorting plugs are installed at P2 or P3. If in the HIGH range, apply a voltage of 50.0 VDC to the input. If in the LOW range, apply a voltage of 5.00 VDC to the input. Connect a frequency counter to TP2. Adjust R6 for an indication of 5000 Hz on the frequency counter. When finished disconnect the voltage source from the input and disconnect the frequency counter.

### **5.2 TEMPERATURE CALIBRATION**

First, you must determine if you want temperature in Fahrenheit or Celsius units. Install a LM34 at IC5 for Fahrenheit scale. Install a LM35 at IC5 for Celsius scale (alternatively just use whatever device you have and then apply a conversion formula to convert between Fahrenheit and Celsius<sup>3</sup>). Install a jumpers at P1 and P3 and ensure that no jumper is installed at P2. Connect a digital voltmeter to TP3 (+) and ground (-). Adjust R14 for a +1.000 volt indication on the digital voltmeter.

Connect a digital voltmeter to TP4 (+) and TP3 (-). Connect a frequency counter to TP2. Take the voltage measured by the voltmeter, in volts, and multiply this value by 1000 and then add 1000 and call it F-WANTED. Adjust R6 for an indication of F-WANTED Hz on the frequency counter. The frequency output by VTF-1 now reads in tenths of degrees with a 100 degree offset.

## **6. TEMPERATURE CALCULATION EXAMPLES**

Below are examples of how to convert frequency measurements to temperature. For example, if the frequency measured was 1683 you would first divide the frequency by ten (168.3) and then subtract 100 (68.3) for a temperature of 68.3 degrees. If the frequency measured was 783 you would first divide by ten (78.3) and then subtract 100 (-21.7) for a temperature of -21.7 degrees. The units of temperature are Fahrenheit if IC5 is a LM34 or Celsius if IC5 is a LM35.

## **7. POSITIVE ONLY TEMPERATURES**

If you don't expect to deal with negative temperatures you can configure VTF-1 to measure without the 100 degree offset. To do this remove IC4 and install a jumper in the board between the holes for IC4pin11 and IC4pin7. Forget adjusting R14 as it now has no effect. Also, during calibration don't add in the 1000 Hz offset. Now the frequency measured can simply be divided by 10 to determine the temperature.

## **8. RESISTOR TOLERANCES**

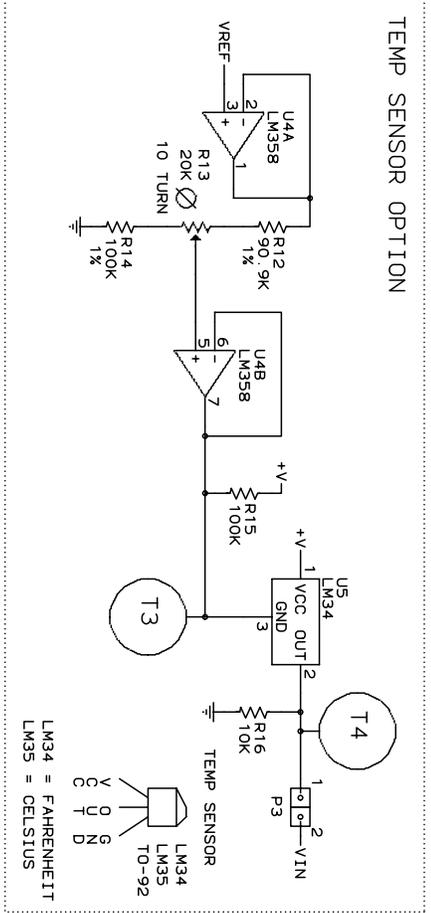
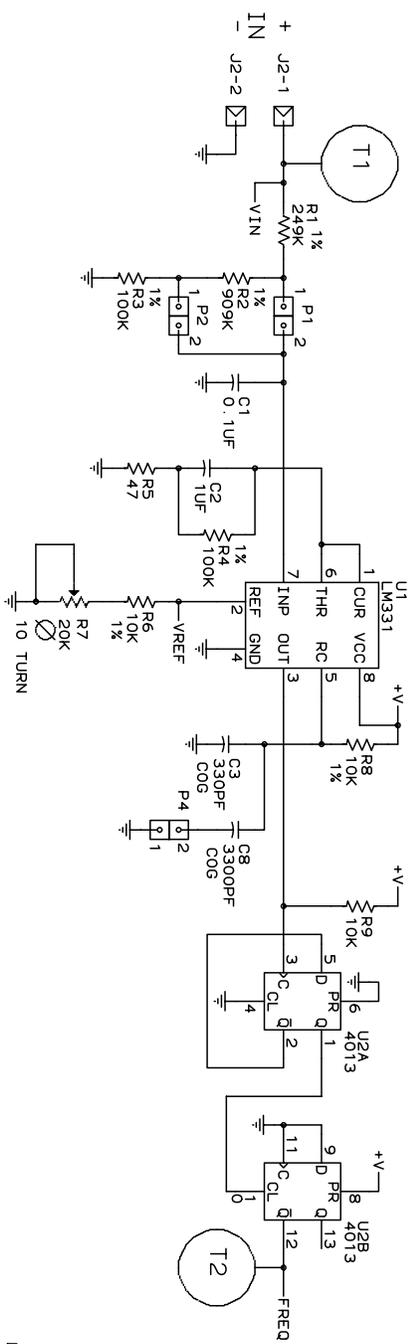
There are several places on this board where it looks like 1% resistor are specified without good reason (for example, in series with a pot). However, in several places 1% resistors are used because of their stability

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<sup>3</sup>  $F = (9/5 * C) + 32$ .  $C = (F - 32) * (5/9)$ .

over temperature instead of their tight absolute tolerance. Don't change these resistor tolerances unless you are not concerned about temperature drift.

————ooOoo————

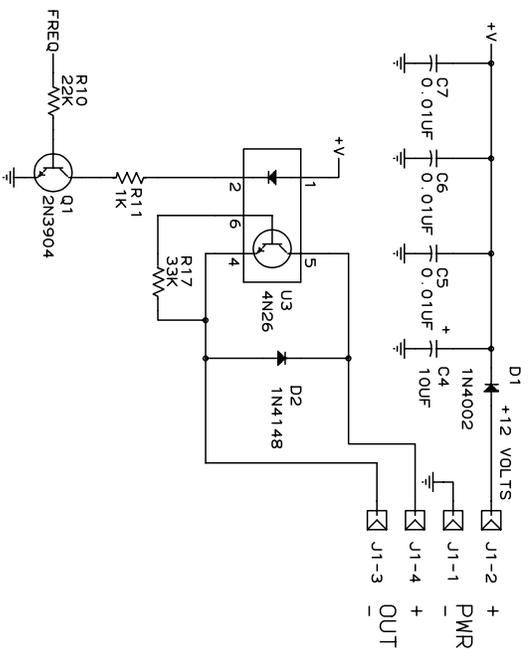


LM34 = FAHRENHEIT  
LM35 = CELSIUS

JUMPER SETTINGS				
SOURCE	P1	P2	P3	P4
J2 0-1 VDC	IN	OUT	OUT	OUT
J2 0-10 VDC	IN	OUT	OUT	IN
J2 0-100 VDC	OUT	IN	OUT	IN
TEMPERATURE	OUT	OUT	IN	IN

NOTES:

- 1) IC4 PIN 8 TO +V, PIN 4 TO GND
- 2) USE LM34 FOR FAHRENHEIT, LM35 FOR CELSIUS



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VOLTAGE TO FREQUENCY SENSOR  
WITH TEMPERATURE SENSOR

FILE: MCVTF	ENGR: PBN	REV 0
ORIG: 901101	LST MOD: 990420	SHT: 1 OF 1