

## AN001 - Interfacing Type K Thermocouples to the Chickadee XL SBC

### Topic

This application note describes how to interface a type K thermocouple to the Chickadee XL SBC. There are other techniques for interfacing thermocouples, but the emphasis here is on medium accuracy, low complexity, and low cost. This TC application covers a temperature range of 0 to 800 °C.

### The Challenge

Thermocouples (TC's) produce very low voltage differentials which must be amplified before A/D conversion. In addition, TC's may have common mode voltages (which appear from each terminal with respect to ground) many times that of the differential voltage. The common mode voltage must be compensated for before A/D conversion. TC's are also temperature-relative; the voltage which appears across the TC terminals is proportional to the temperature difference between the TC junction and the TC termination. In order to get an absolute temperature measurement, the TC must be compensated with a reference point whose absolute temperature is known. This is known as "cold junction compensation", or "ice point compensation". This reference point must be at the same temperature as the TC termination. In order to maintain accuracy, special wiring techniques must be used to eliminate errors due to thermocouple effects in TC wiring. It may also be necessary to detect an open circuit due to TC damage or disconnection. Since TC's are not linear over a wide temperature range, some form of linearization may be required.

### The Solution

Modern IC technology has greatly simplified the interfacing of TC's. The Analog Devices AD595 Monolithic Thermocouple Amplifier with Cold Junction Compensation offers an elegant, simple, low cost, and complete solution to TC signal processing. TC parts and supplies may be obtained from Omega Engineering. In this application note the following items are used:

- 1 Chickadee XL SBC with ADC option (Bagotronix)
- 1 PCC-SMP-K SMP-miniature size TC circuit board connector (Omega Engineering)
- 1 Type K TC with SMP connector (Omega Engineering)
- 1 AD595AQ Monolithic Thermocouple Amplifier IC (Analog Devices)
- 1 piece of experimenter's prototyping board with solder pads
- Various electronic parts as shown in Figure 1

The schematic shown in Figure 1 is for a single TC channel. The actual test circuit that we built had four TC channels, so the TC channel circuitry was replicated for each channel. We also used a Type K TC from a Fluke temperature meter instead of a Type K TC from Omega Engineering, but any Type K TC with the SMP connector will work.

### Theory of Operation

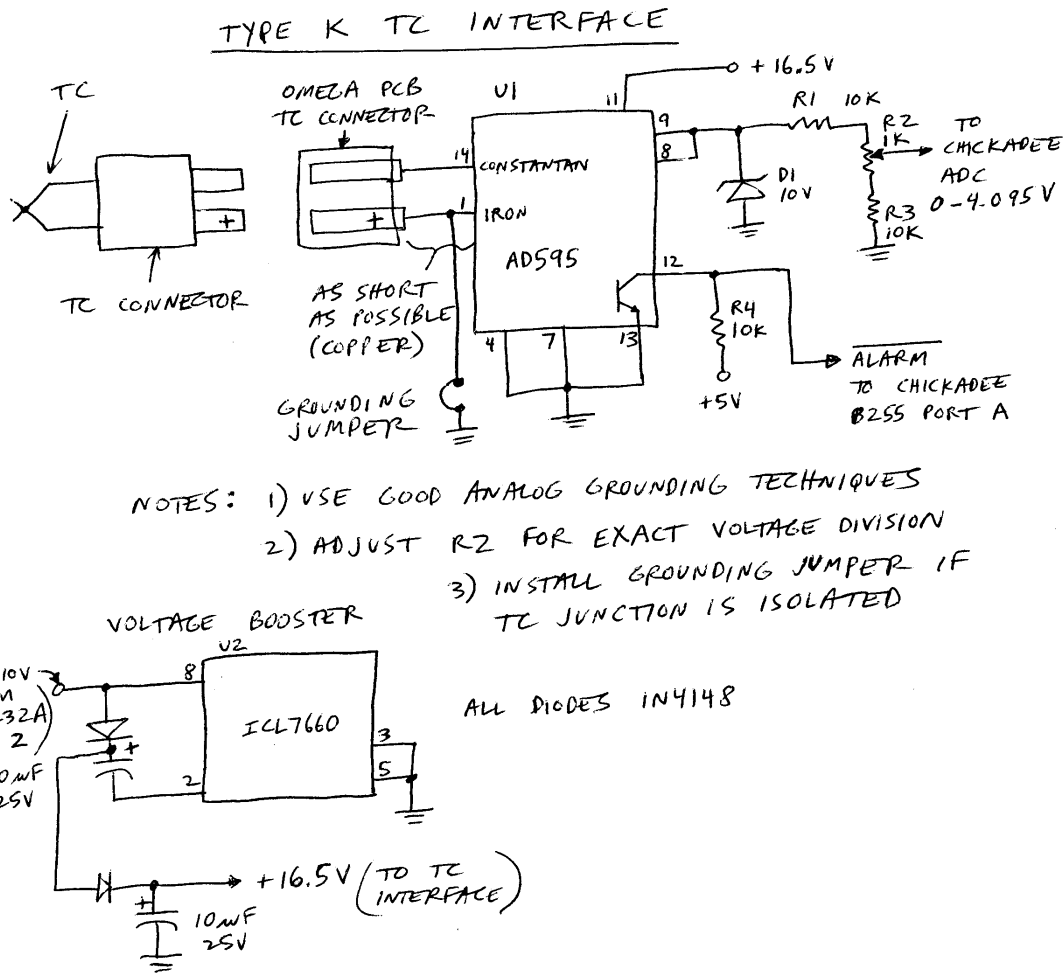
The TC connects to the AD595 (U1) pins 1 and 14 via the PCC-SMP-K TC circuit board connector. It is vital to keep the connector-IC junctions as short as possible to minimize temperature gradient. The processed output from pin 9 is fed back to pin 8 to close the gain loop of U1. Pin 9 output voltage is divided by 2 by the resistor divider R1, R2, and R3. This results in a 0 to 4.095 V input (5mV per °C) to the ADC for the temperature range of interest. U1 pin 9 is also clamped to +10V by the zener diode D1. This is necessary since it is possible for U1 to have an output that exceeds +10V for temperatures above 960 °C. This would result in an ADC input voltage of greater than +5V, which would cause errors on other ADC input channels and possible damage to the ADC.

The alarm output of U1 pin 12 is pulled up to +5V by R4 and connected to a 82C55 pin on the Chickadee header JP11. The 82C55 pin is configured by software as an input. If the TC is OK, reading the 82C55 input gives a high logic level. If the TC has been disconnected or damaged, reading the 82C55 input gives a low logic level.

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For the circuit to work properly, there must be a DC path to ground for U1 pins 1 and 14. Often this path is provided by the physical attachment of the TC to a metallic object of interest. If the TC is isolated from the object being measured, or if the object is non-conductive or not grounded, a ground connection can be made with the grounding jumper shown. If a low resistance ground connection causes ground loops or other electrical problems, a 10K resistor may be used instead of the jumper.

In order to span a range of 0 to 800 °C, the AD595 requires a power supply voltage of at least +10V. If +12V is available from elsewhere in the system, it can be used. In this case, there was no available system voltage other than +5V. The Chickadee has a MAX232 chip (U12) which has a +10V output. However, the +10V output is actually less than +10V due to loading from the serial port. Since the AD595 requires so little current to operate, the +10V output of the MAX232 IC (U12) on the Chickadee was used as input to a voltage booster circuit (see Figure 1). The output of the voltage booster is unregulated but is typically about +16.5V for four TC channels.



**Figure 1**

### The Software

The TC interface software was written in Borland C v3.0. Other C compilers and versions can be used, although some minor modifications may be required. The program consists of the following files, compiled and linked to produce a 16-bit DOS EXE:

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- CSFC8255.C
- CSFCADC.C
- CHICKADEE.C
- CHKTC.C

Using the TRANSFER.EXE utility, the program CHKTC.EXE was transferred to the Chickadee XL flash disk. Then the program was run:

```
B>chktc
Strike the 'X' key to quit, any other alphanumeric key to sample.
```

```
TC0: +0 C
TC1: +10 C
TC2: +13 C
TC3: +13 C
```

Then a TC was disconnected, and the TC inputs were sampled again:

```
TC0: +0 C
TC1: +9 C
TC2: +13 C
TC3: NC
```

The disconnected TC, #3, was indicated by a "NC" (Not Connected) warning from the program.

The source file for the CHKTC.EXE program is listed here and is also available with the other source files in ZIPped form from the Bagotronix website.

### Program Listing

```
/******
Bagotronix
1019 Crossing Brook Way
Tallahassee, FL 32311

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Filename:      chktc.c
Programmer(s): Ivan Baggett
Description:    Chickadee(tm) example application for thermocouples.
comments:      Does not linearize thermocouple. Use AD595 data sheet
               type K, Table I, p. 3. A lookup table with interpolation
               is required to obtain accurate temperatures above 100 C.
*****/

#include <dos.h>
#include <stdio.h>

#include "stdinc.h"
#include "chickade.h"
#include "csfcadc.h"
#include "csfc8255.h"

#define _getch getch          // for Borland console

IOPARMS pia = { CHICKADEE_8255, 0 };

int main (void) {

    BOOLEAN done = FALSE;
    int c, i;
    UWORD u;
    UBYTE b;
```

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```
/* initialize 8255: Port A = input, Port B = output, CL & CH = output */
_8255_init (&pia, INPUT, OUTPUT, OUTPUT, OUTPUT);

printf ("Strike the 'X' key to quit, any other alphanumeric key to sample.\n\n");

while (!done) {
    while (!kbhit());
    c = _getch();
    if (c == 'x' || c == 'X')
        done = TRUE;

    printf ("\n");
    for (i = 0; i < 4; i++) {
        // 1mV/LSB for MAX186 using internal reference (4.095V)
        u = ADCget (MAX186, (UBYTE)i, 0); /* MAX186, channel i, 0 acq delay */
        /* 12-bit ADC result is normalized to MSB, so denormalize it (/16) */
        u /= 16;
        // 5mV/C after resistor divider (2:1) on AD595 output (pots)
        u *= 2;
        // 10mV/C for AD595 and type K thermocouple
        u /= 10;

        // determine if thermocouple is connected
        // 0 -> disconnected, Port A[4..7] -> TC[0..3]
        if (!_8255_getbit (&pia, _8255_PORTA, (UBYTE)(i+4)))
            printf ("TC%d: NC\n", i);
        else
            printf ("TC%d: +%u C\n", i, u); /* to remote console */
    }
}

return 0;
}
```