Using the Frequency Counter (SCOUNT)

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Product reference: P025, P029, and P039

Introduction

Many instruments produce an output signal consisting of an oscillating voltage with a frequency that is related to the measured parameter. For example, the SeaBird thermometer model SBE3 produces an ac-coupled square wave with a frequency between 3 to 6 kHz range that is a very precise (±0.001ºC) function of temperature. Propeller current meters produce pulses with a frequency proportional to the speed of flow past the instrument. The purpose of the SCOUNT boards is to convert such frequency signals into binary numbers with a high degree of precision (1.5 ppm, parts per million). The SCOUNT boards are a part of the Ocean Data Acquisition System (ODAS) used in instruments produced by Rockland Scientific International (RSI). There are three versions of SCOUNT – P025R is an eight-channel version, while P029R is a two-channel version, and P039 is a remote transceiver with an integrated two-channel frequency counter.

Principle of Operation

The SCOUNT uses a precision (1.5 ppm) temperature compensated crystal oscillator to produce a number that is proportional to the period of the oscillating signal. The analog front-end converts the oscillating voltage in to a logic-level square wave with a frequency identical to the frequency of the input. These logic level signals are routed to a Xilinx programmable logic chip. Each logic chip processes 2 channels.

The logic processor continually estimates the period (not the frequency) of the input signal and places it into an internal register. It does this by counting the reference clock for *P* periods of the input signal. This produces a number proportional to the period of the input signal. The number of input cycles, *P*, is user selected by 4 jumpers labeled P_Count_Set. The location and usage of these jumpers are discussed below.

There is one set of quadruple jumpers for each channel. The number produced by the logic chip is

$$N = \frac{f_R P}{f_S} \tag{1}$$

where f_S is the input frequency (the SeaBird thermometer, for example), f_R is the reference frequency (usually 24 MHz, ±1.5 ppm), and P is the number of periods of the input selected with P_Count_Set. The internal logic of the free-running period counter in the Xilinx processor is summarized in Figure 1.

The number, N, produced by SCOUNT is 32 bits long. Therefore, the output has to span two addresses in order to provide the full 32 bits of *N*. When the SCOUNT is interrogated with its even address, it responds by (1) transferring the number, *N*, in the internal register to the output register and (2) placing the lower (least-significant) 16 bits of the output register on to the instrument bus. When the SCOUNT is interrogated with its odd address, it only places the 16 most significant bits of the output register on to the instrument bus and leaves the output register unchanged. Reading the even address followed by the odd address completes the transfer of the entire 32 bits of the number to the ODAS data acquisition system. It is important to remember that the internal register is updated continuously without any intervention by the user. The updating of the output register is done by interrogating the SCOUNT board with an even address. Interrogation of the SCOUNT board with an odd address does not update the output register. Therefore, the even address must always be read before the odd address. The odd address can be interrogated at any convenient time *after* the even address. The odd address does not have to follow immediately after the even address. The interrogation logic, or the reading of data from the SCOUNT is summarized in Figure 2

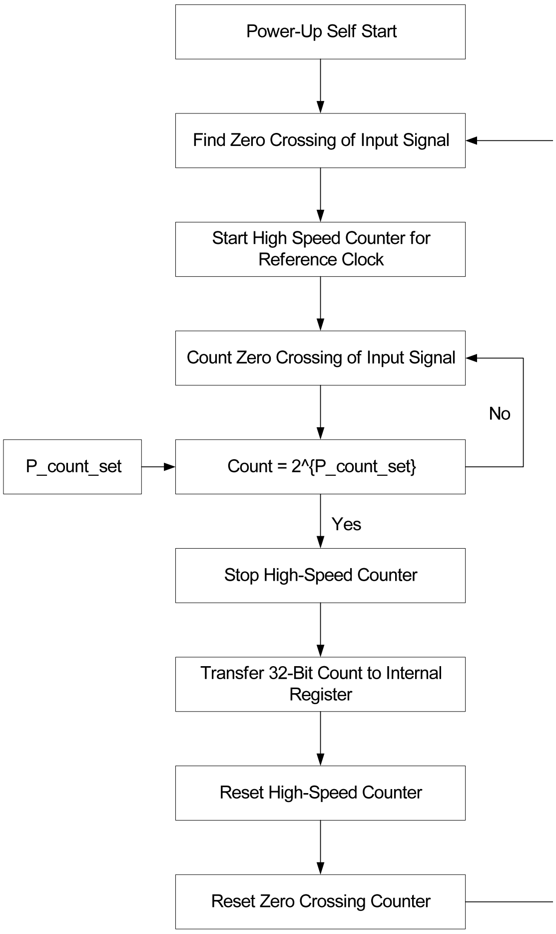

Figure 1. Internal logic of the free-running period counter in the Xilinx programmable logic chip of SCOUNT.

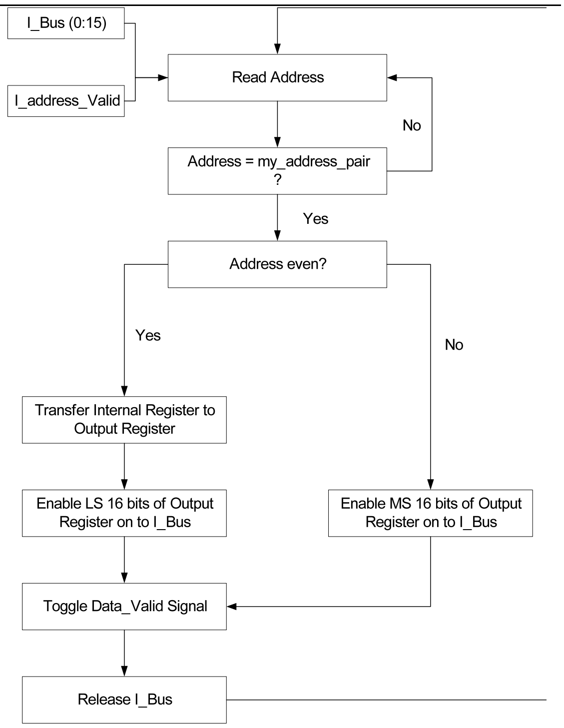

Figure 2. Summary of logic of reading data from the SCOUNT.

Power

The SCOUNT circuitry is energized by 3.3V supplied by the instrument bus. Details are given below for each board. Connectors are provided to pass 12VDC to the Sea-Bird SBE3F and SBE4C sensors and to accept the frequency signal reported by these sensors.

Reference Clock

The SCOUNT board requires a reference clock. This reference signal is normally supplied by the precision oscillator on either RTRANS or UTRANS for product P025 and P029. It is transferred to these boards in the form of a low-voltage differential signal and converted to logic levels with an onboard chip. On P039 the SCOUNT uses the onboard oscillator, although an external reference clock can be provided for cases that require more than 2 channels. There is an onboard 100 Ω termination resistor for the clock input line. When multiple SCOUNTS are used, the 100 Ω resistor must be placed on the last board in a daisy chain of boards.

P025 Details

The P025 SCOUNT is an 8-channel frequency counter (Figure 3). It is a large form-factor board that uses the 16-bit bidirectional parallel instrument bus (PIB). Details of this bus are given in Application Note AN-009.

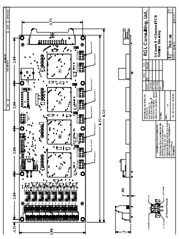

Figure 3 Physical layout of SCOUNT-8 board (Product P0025R01).

The input path for the frequency signals is provided by connector J3 (Table 1). Each channel uses 4 lines. One is for the 12V power to energize A Sea-Bird instrument (such as the SBE3F thermometer), a ground line that serves as the power return and is usually the reference line for the oscillating signal, a positive input which is usually the Sea-Bird signal and a negative line that can be used for differential voltage signals but is usually tied to ground for AC-coupled signals, such as from a Sea-Bird thermometer.

Contact Number	Function	Contact Number	Function
1	12VDC	17	12VDC
2	Ch_0_IN+	18	Ch_4_IN+
3	Ground	19	Ground
4	Ch_0_IN-	20	Ch_4_IN-
5	12VDC	21	12VDC
6	Ch_1_IN+	22	Ch_5_IN+
7	Ground	23	Ground
8	Ch_1_IN-	24	Ch_5_IN-
9	12VDC	25	12VDC
10	Ch_2_IN+	26	Ch_6_IN+
11	Ground	27	Ground
12	Ch_2_IN-	28	Ch_6_IN-
13	12VDC	29	12VDC
14	Ch_3_IN+	30	Ch_7_IN+
15	Ground	31	Ground
16	Ch_3_IN-	32	Ch_7_IN-

Table 1. Contact assignments for Connector J3 of the 8-channel SCOUNT, part P025.

The signal front-end of the 8-channel SCOUNT has been designed to handle a wide variety of signal types. Jumpers on the front-end must be configured to match the type of frequency signal used, and their configuration is summarized in Table X.

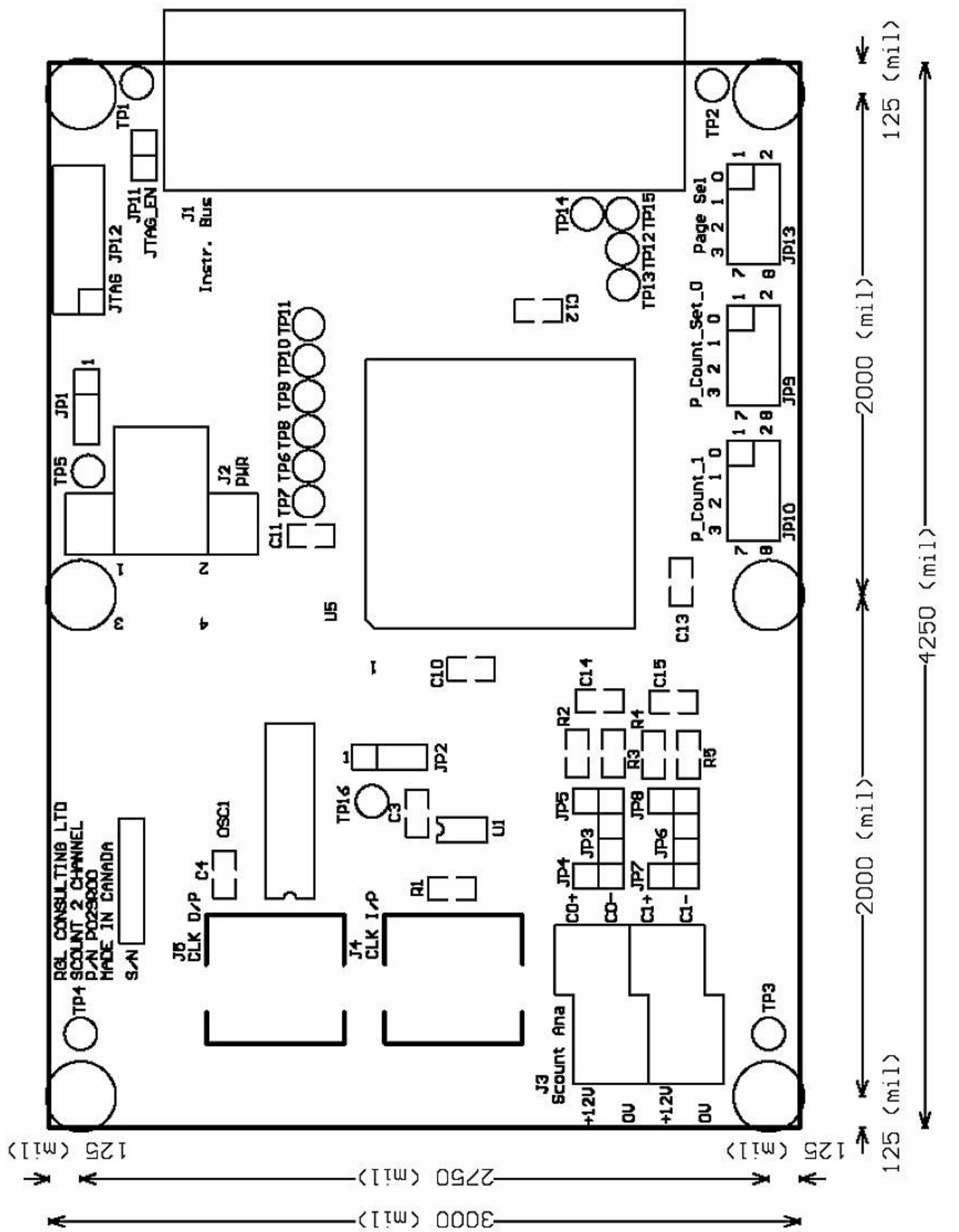

Figure 4. Silk-screen of SCOUNT-2, product P029R00.

Addressing

The SCOUNT board is assigned one of sixteen possible base addresses, or pages, using the 4 jumpers on JP4 (Page Select). These base addresses are 0, 16, 32, …, 240. Each channel of the SCOUNT occupies 2 address spaces relative to the base (page) address. Thus, the SCOUNT-8 occupies an entire page of addresses, while the SCOUNT-2 claims only the lower 4 addresses of a page. Each device on the Instrument Bus must occupy a unique portion of the address space (0-255) and there can be no conflicts for an address. Typical page selections and the corresponding jumper configurations are shown in Table 2.

Page Or Base Address	JP4-0	JP4-1	JP4-2	JP4-3	SCOUNT-8
	JP13-0	JP13-1	JP13-2	JP13-3	SCOUNT-2
0	0	0	0	0	
16	1	0	0	0	
32	0	1	0	0	
48	1	1	0	0	
64	0	0	1	0	
128	0	0	0	1	
240	1	1	1	1	

Table 2. Selecting the base address of the SCOUNT board. This table shows 7 of 16 possible choices.

Relative Address	SCOUNT-8 Channel Number	SCOUNT-2 Channel Number
0-1	0	0
2-3	1	1
4-5	2	
6-7	3	
8-9	4	
10-11	5	
12-13	6	
14-15	7	

Table 3. The relative address of the channels on an SCOUNT board. Each channel occupies 2 addresses.

The relative address is determined by the channel number of an SCOUNT board (see Table 3. The relative address of the channels on an SCOUNT board. Each channel occupies 2 addresses.

). The actual address of a particular channel is the base address plus the relative address. Thus, if the board is assigned page 32, then the addresses of channel 4 are 40 and 41. The response of the board to the even and odd addresses is different and is discussed below.

Analog Front-End

Connector J3 is used to route the frequency signals into the SCOUNT board and it is also (optionally) used to energize the instruments connected to the SCOUNT board. Frequency output devices, such as the SeaBird thermometer, are frequently energized by 12VDC. To facilitate the wiring, the 12VDC power is available on connector J3. This power is input into the SCOUNT board using the Molex power connector J2. See Figure 3 for the location of these connectors.

For every channel, there is a positive and a negative signal input. There are also 3 pairs of jumpers that must be configured for each channel input to optimize the response for a given type of signal. The most common type of signal is a zero-mean periodic waveform, such as the ac-coupled square wave produced by the SeaBird thermometer. Any such periodic waveform with an amplitude greater than 50 mV is detected and converted into a logic level square wave by the analog front end. The SCOUNT can also accommodate (unipolar) logic level signals with a logic “high” greater than 1.5 Volts and a logic low that is less than 0.7 V. Finally, SCOUNT can also handle differential signals with amplitudes between 0.05 and 15 volts. An example of the jumper configuration for channel 0 is shown in Table 4. Other channels have identical arrangements of jumpers but the jumper numbers are different. The jumper numbers for the other channels are on the board silk screen and are also shown in Figure 3.

C0+ = positive input, C0- = negative input (usually ground for non-differential inputs)			
Input Type	JP6	JP7	JP8
AC-Coupled waveforms and bi-polar signals	IN	IN	OUT
Logic Level Signals with low = 0 and high>1.5V	OUT	IN	IN
Differential Signals with common mode between -7 and 12 V.	IN	OUT	OUT

Table 4. Jumper configuration of the signal input for various types of signals. Jumpers JP6-8 refer to Channel 0 on the SCOUNT-8 board and also to Channel 1 on the SCOUNT-2 board. Other channels have other jumper numbers. Please, refer to the silk screen labels next to the signal inputs on the circuit board for the actual numbers of the jumpers for the other channels.

Logic Circuit

P_Count_Set

The jumpers on P_Count_Set are used to select the *exponent* of the number of periods of the input signal used to estimate the length of the input period. The period P and the corresponding jumper settings are summarized in Table 5. The location of the jumper group for each channel is shown in Figure 3

P	$\log_2 P$	JPXX-0	JPXX-1	JPXX-2	JPXX-3
2	1	IN	OUT	OUT	OUT
4	2	OUT	IN	OUT	OUT
8	3	IN	IN	OUT	OUT
16	4	OUT	OUT	IN	OUT
32	5	IN	OUT	IN	OUT
64	6	OUT	IN	IN	OUT
128	7	IN	IN	IN	OUT
256	8	OUT	OUT	OUT	IN
512	9	IN	OUT	OUT	IN
1024	10	OUT	IN	OUT	IN
2048	11	IN	IN	OUT	IN
4096	12	OUT	OUT	IN	IN
8192	13	IN	OUT	IN	IN
16384	14	OUT	IN	IN	IN
32768	15	IN	IN	IN	IN

Table 5. Jumper selection to choose the number of periods of the input signal that are used to estimate the length of the period of the input signal. At least one jumper *must* be installed. The choice $P = 1$ is not permitted.

Regardless of the choice of P, SCOUNT will return valid numbers representing the period of the input signal. However, for best results, P should be chosen carefully. The internal register is updated every P periods of the input signal. Therefore, P should be chosen to given an update rate approximately equal to the channel sampling rate. This means that the user must have some *a priori* knowledge of the frequency input and its range of variation because the update rate is

$$\frac{f_s}{P}. \tag{2}$$

If the update rate is slow (P is too large) compared to the sampling rate, then redundant values are provided by SCOUNT. That is, the values in the internal and the output registers may not changed between successive reads and the same value will be returned twice or more often. The true sampling rate is then effectively set by the internal free-running counter.

If, on the other hand, the update rate is too high (P is too small), then many values are missed and successive reads do not represent well the average period of the input signal over the time between samples. Moreover, because the statistical uncertainty of an individual count is ±1 (not ±0.5), and because the actual value of the count is small (when P is large), the relative uncertainty of the values is high.

We will use the SeaBird SBE3 thermometer as an example of choosing P. Let the sampling rate be 32 samples per second. The frequency range of the SBE3 is 3 to 6 kHz. The slowest update rate of the internal register occurs when the frequency is at the bottom of its range, namely 3000 Hz. The slowest update rate is then

$$\frac{f_s}{P} = \frac{3000}{P} = 23.4 \text{ updates per second} \tag{3}$$

when P = 128, and the fasted update rate is twice this value (which occurs when the input frequency is 6000 Hz). With a choice of P = 128 there will be very few redundant values and the values will very nearly represent a true average for the time interval between samples. Choosing P to be 64 or 256 would also give reasonable performance. For the smaller value of P = 64, the number returned by SCOUNT would represent the average period for approximately half of the time interval between samples. For the larger value of P = 256, about one-half of the values returned by SCOUNT will be redundant, and they will represent an average over an interval slightly longer than the time between samples. Compared to P = 128, the values returned for P = 256 will be twice as large and twice as precise. However, about half will be redundant and, thus, there is no advantage (but also no harm) in using P = 256.

Low-frequency signals

Some instrument provide relatively low-frequency signals compared to the SeaBird thermometers. For example, propeller anemometers usually produce one or two pulse per revolution and spin in the 3 to 100 Hz range. The standard logic circuit in the Xilinx programmable chip is not well suited for such applications because the update rate will be relatively slow with the restriction of $P \geq 2$. A special version of the logic can be loaded into the Xilinx logic chip so that the period is estimated on every pulse from the propeller anemometer. P = 1 is fixed for these versions of the Xilinx logic. Please, consult the factory for installation of this special logic on the channel(s) of your choice.

Specifications

Frequency input range	0 to 100 kHz
Minimum Input Voltage	100 mV peak-to-peak
Maximum Input Voltage	24 V peak-to-peak
Input types	AC-coupled periodic waveforms DC-coupled periodic waveforms with zero crossing Logic level waveforms with high > 1.5 V Differential periodic waveforms.
Power	3.3 V for Logic, 10mA, from instrument bus or external connector User-supplied voltage for instruments, usually 0 and 12 VDC.
Reference frequency	Externally supplied in LVD voltage. Usually, 24 MHz, 1.5 ppm, supplied via 3-pin DIN connector. 100 ohm termination On-board oscillator available by request.
Number of input channels	8
Size	8.9 X 3.0 X 0.7 inches 226 X 76.2 X 18 mm

Table 6. Specification summary for SCOUNT-8 (product P025R01).

Frequency input range	0 to 100 kHz
Minimum Input Voltage	100 mV peak-to-peak
Maximum Input Voltage	24 V peak-to-peak
Input types	AC-coupled periodic waveforms DC-coupled periodic waveforms with zero crossing Logic level waveforms with high > 1.5 V Differential periodic waveforms.
Power	3.3 V for Logic, 2.5mA, from instrument bus or external connector User-supplied voltage for instruments, usually 0 and 12 VDC.
Reference frequency	Externally supplied in LVD voltage. Usually, 24 MHz, 1.5 ppm, supplied via 3-pin DIN connector. 100 ohm termination On-board oscillator available by request.
Number of input channels	2
Size	4.7 X 3.0 X 0.7 inches 120 X 76.2 X 18 mm

Table 7. Specification summary for SCOUNT-2 (product P029R00).

Circuit Diagrams

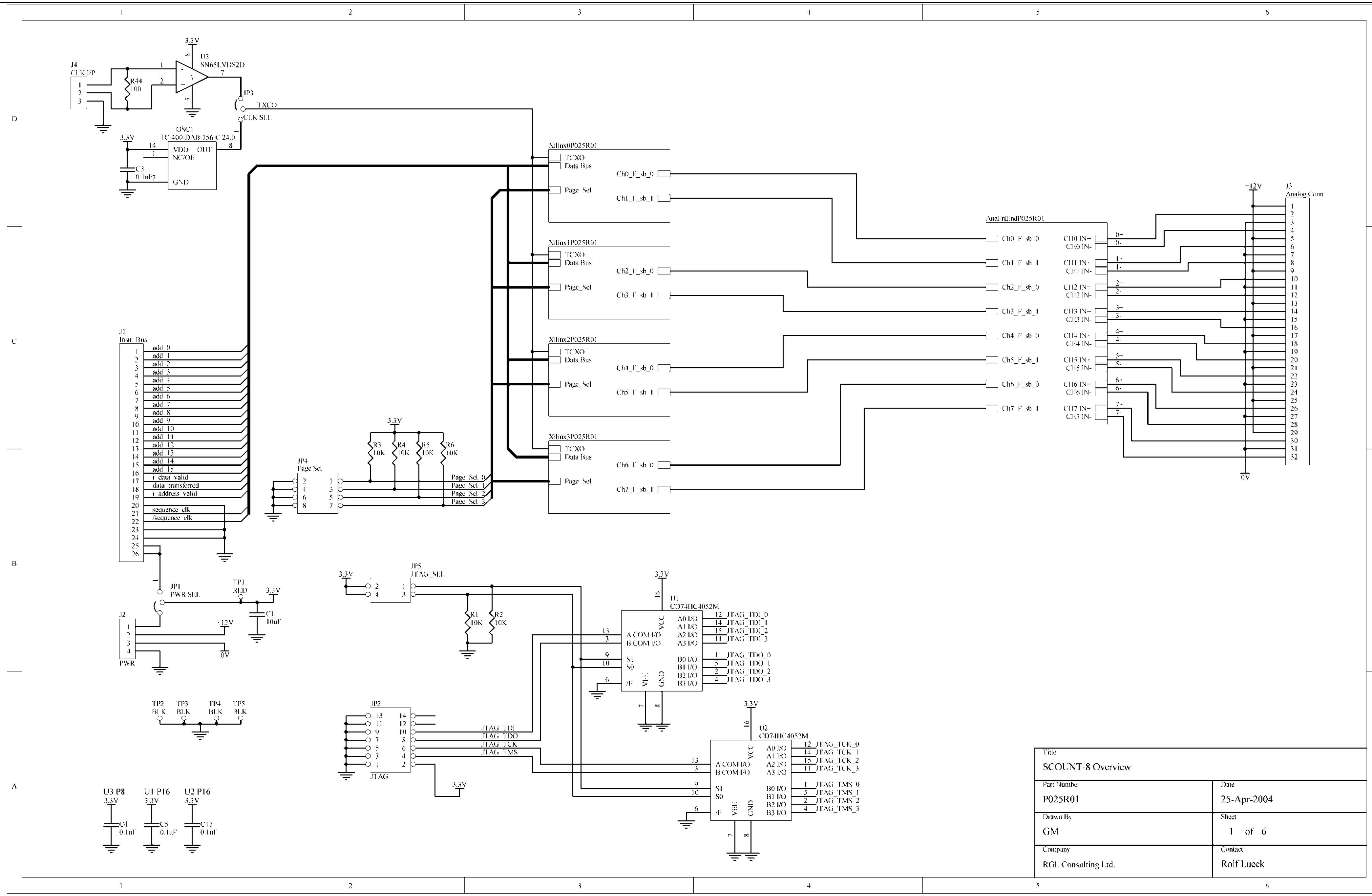

Figure 5. Overview of 8-channel SCOUNT, P025R01 electronics.

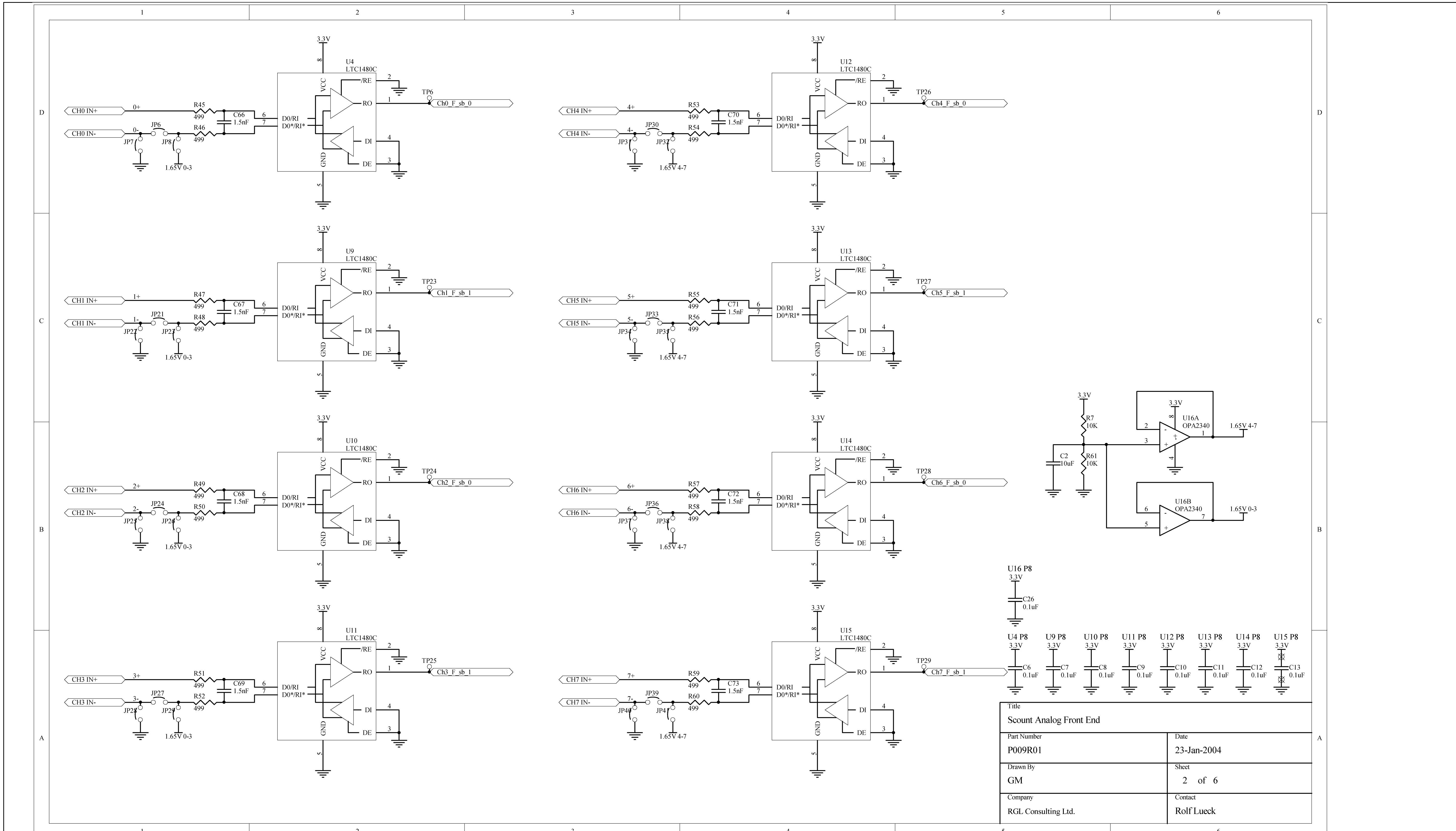

Figure 6. Analog front-end of 8-channel SCOUNT, P025R01.

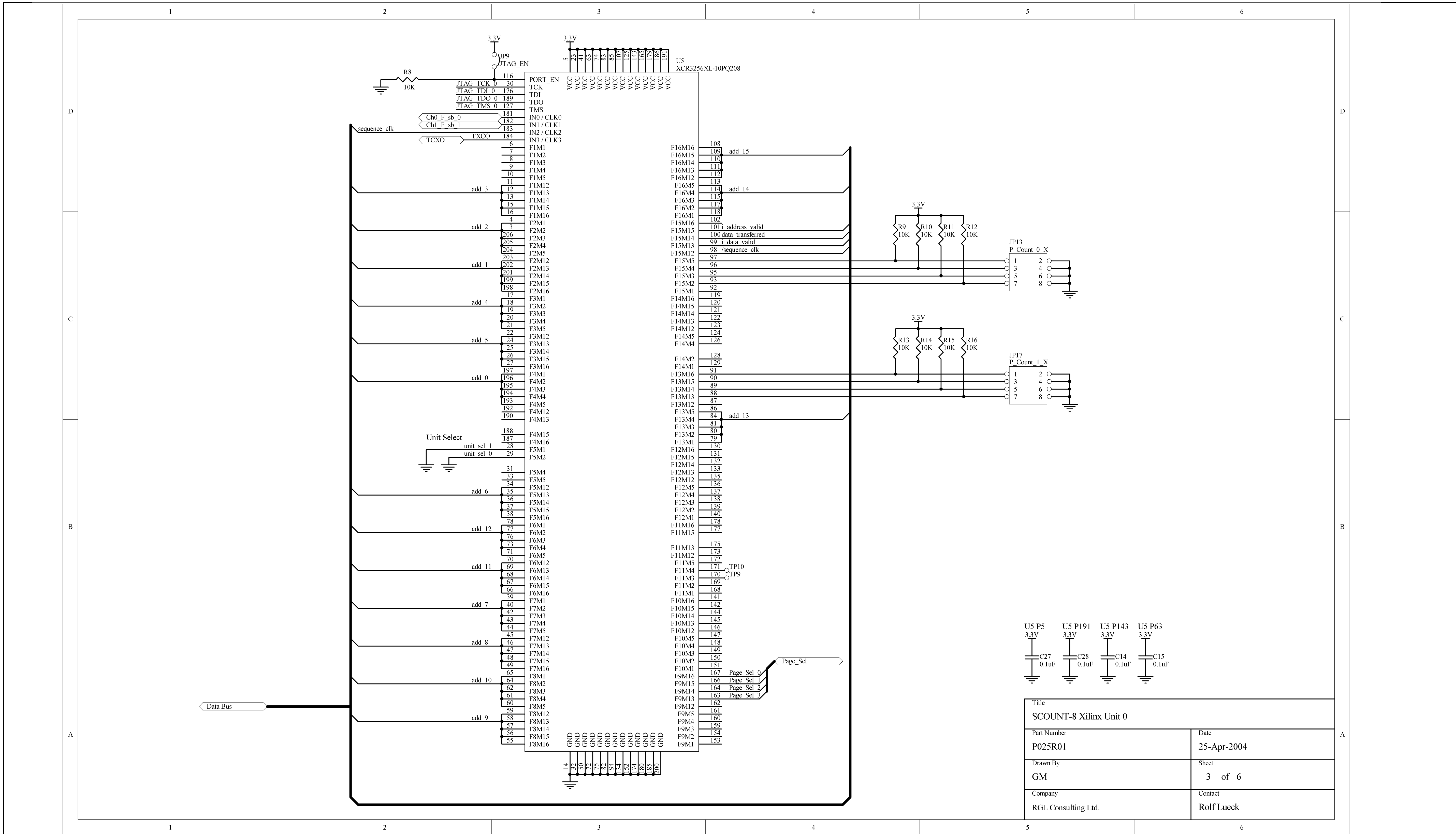

Figure 7. 8-channel SCOUNT, Xilinx CPLD, channels 0 and 1.

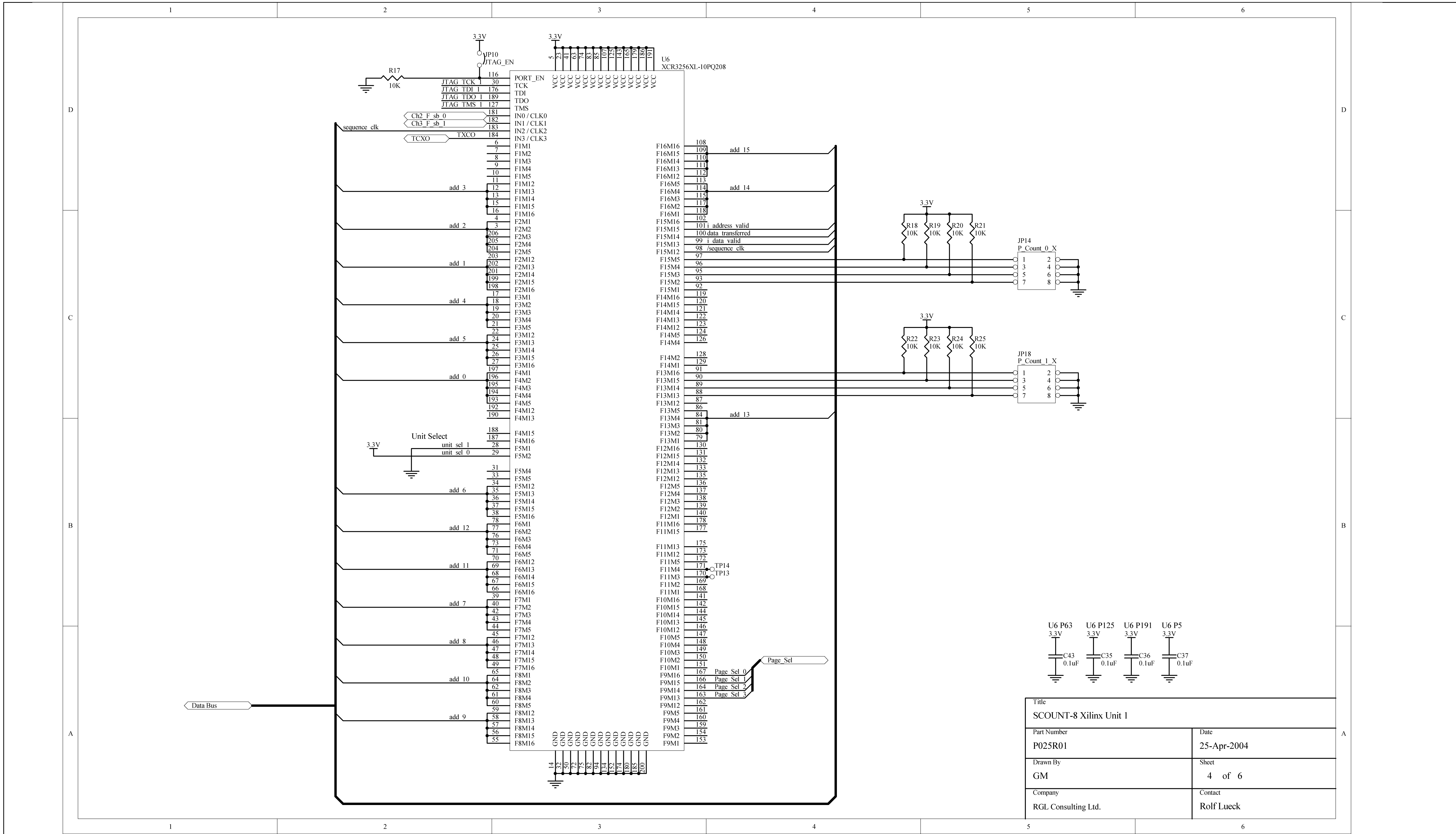

Figure 8. 8-channel SCOUNT, Xilinx CPLD, channels 2 and 3.

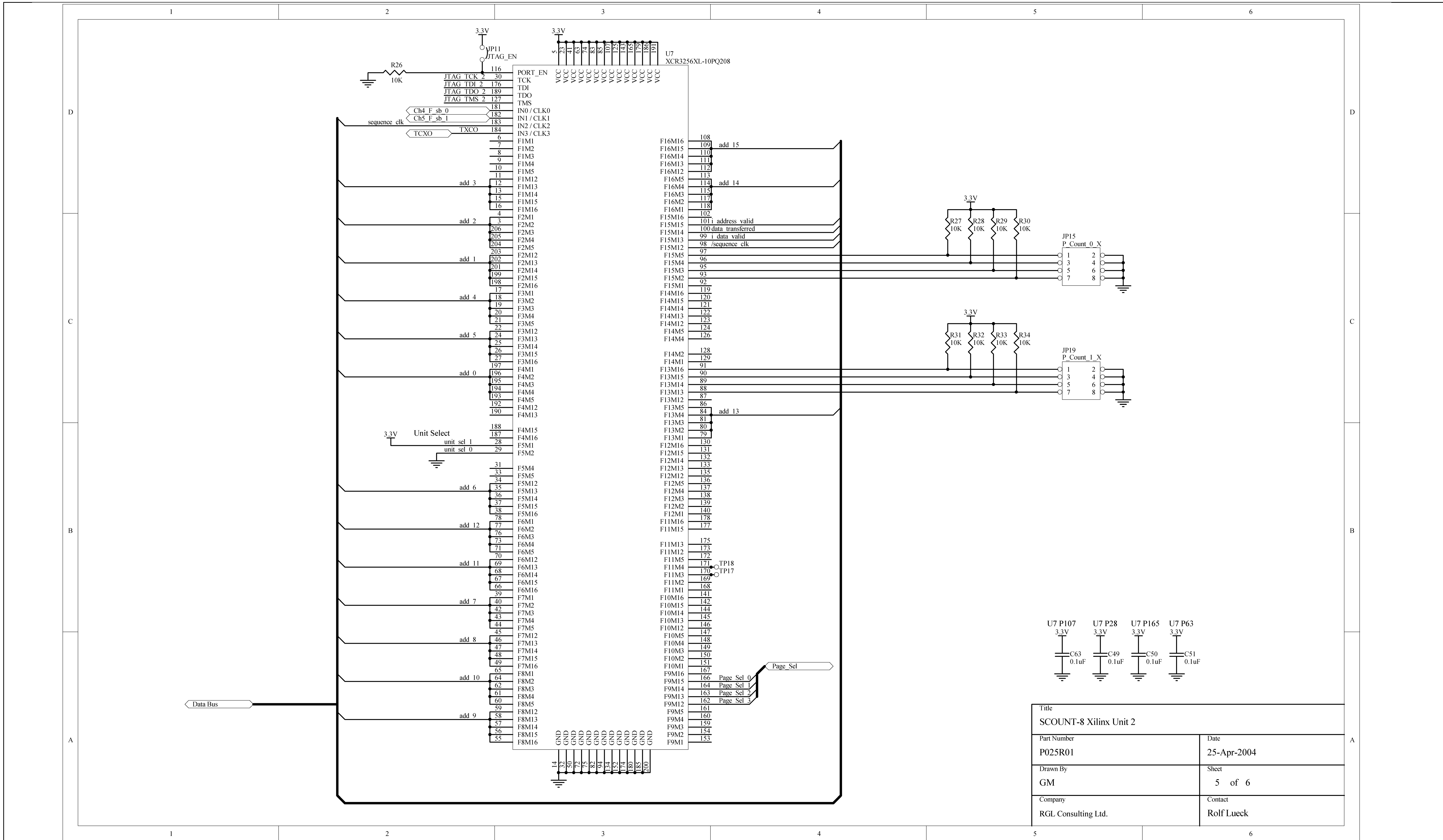

Figure 9. 8-channel SCOUNT, Xilinx CPLD, channels 4 and 5

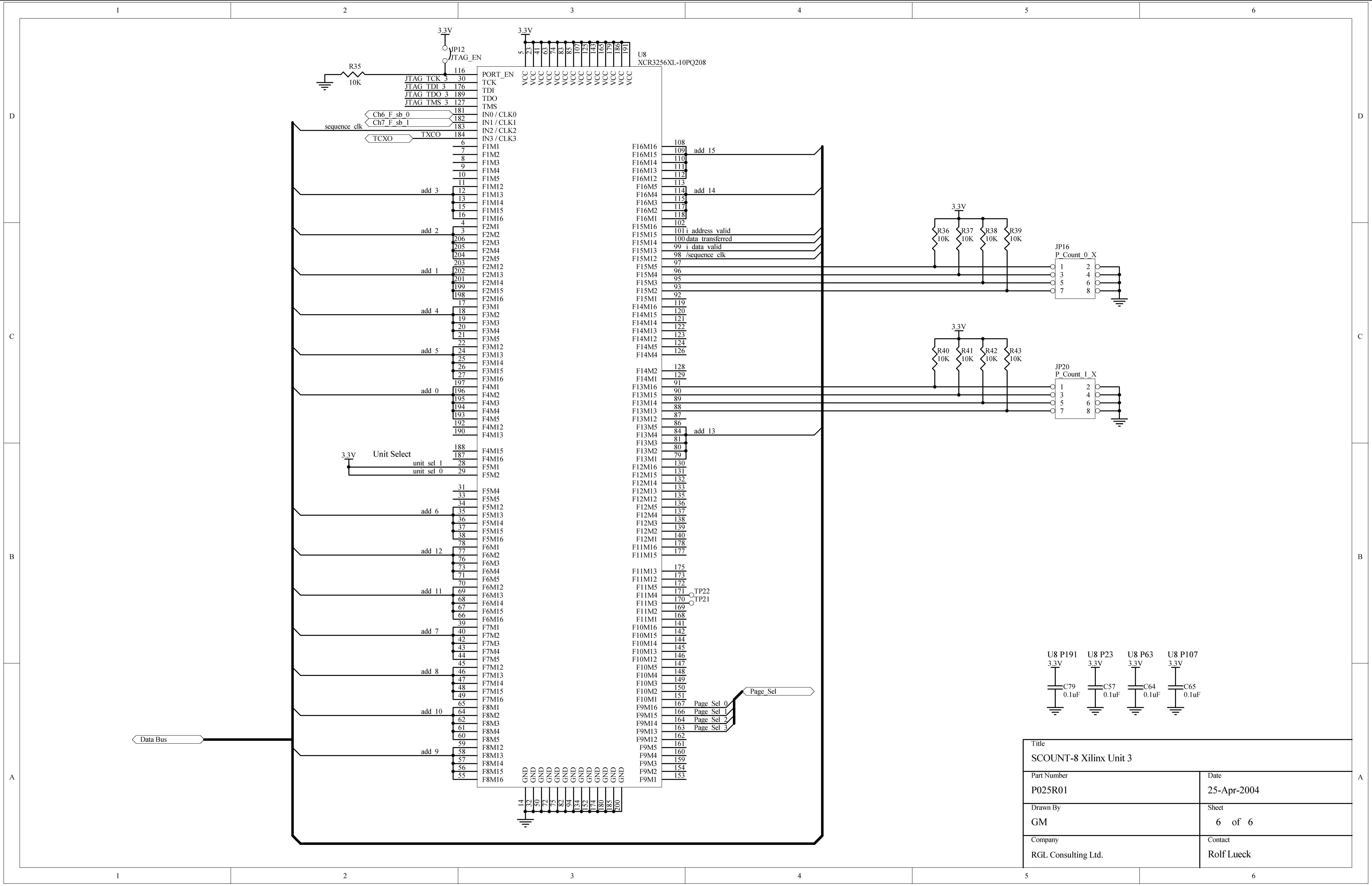

Figure 10. 8-channel SCOUNT, Xilinx CPLD, channels 6 and 7