TLC2543
Evaluation Module

User’s Guide
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About This Manual

This user’s guide provides descriptive information about the hardware and software comprising the TLC2543 evaluation module (EVM). The evaluation module includes a TLC2543 12-bit analog-to-digital converter (ADC) and can be used to assist managers and hardware and software engineers in developing 12-bit ADC applications.

How to Use This Manual

This document contains the following chapters:

Chapter 1 Overview

Provides a general description of the TLC2543 EVM

Chapter 2 Hardware Description and Operation

Describes the features of the TLC2543 EVM hardware and provides operating specifications, schematic diagram, connections, layout, and parts

Chapter 3 Board Layout

Contains illustrations of the board layout and layers

Chapter 4 Part Descriptions

Lists and describes the TLC2543 EVM parts.

Chapter 5 Software Program and Flow Charts

Describes the TLC2543 EVM software program and program flowcharts
Notational Conventions

This document uses the following conventions.

- Program listings, program examples, and interactive displays are shown in a special typeface similar to a typewriter’s. Examples use a bold version of the special typeface for emphasis; interactive displays use a bold version of the special typeface to distinguish commands that you enter from items that the system displays (such as prompts, command output, error messages, etc.).

Here is a sample program listing:

```
0011  0005  0001  .field    1, 2
0012  0005  0003  .field    3, 4
0013  0005  0006  .field    6, 3
0014  0006
```

Here is an example of a system prompt and a command that you might enter:

```
C: csr -a /user/ti/simuboard/utilities
```

- In syntax descriptions, the instruction, command, or directive is in a bold typeface font and parameters are in an italic typeface. Portions of a syntax that are in bold should be entered as shown; portions of a syntax that are in italics describe the type of information that should be entered. Here is an example of a directive syntax:

```
.asect "section name", address
```

.asect is the directive. This directive has two parameters, indicated by section name and address. When you use .asect, the first parameter must be an actual section name, enclosed in double quotes; the second parameter must be an address.

- Square brackets ([ and ]) identify an optional parameter. If you use an optional parameter, you specify the information within the brackets; you don’t enter the brackets themselves. Here’s an example of an instruction that has an optional parameter:

```
LALK 16–bit constant [, shift]
```

The LALK instruction has two parameters. The first parameter, 16-bit constant, is required. The second parameter, shift, is optional. As this syntax shows, if you use the optional second parameter, you must precede it with a comma.

Square brackets are also used as part of the pathname specification for VMS pathnames; in this case, the brackets are actually part of the pathname (they are not optional).

- Braces ( { and } ) indicate a list. The symbol | (read as or) separates items within the list. Here’s an example of a list:

```
{ * | *+ | *– }
```

This provides three choices: *, *+, or *–.
Unless the list is enclosed in square brackets, you must choose one item from the list.

Some directives can have a varying number of parameters. For example, the `.byte` directive can have up to 100 parameters. The syntax for this directive is:

```
.byte value_1 [, ... , value_n]
```

This syntax shows that `.byte` must have at least one value parameter, but you have the option of supplying additional value parameters, separated by commas.

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This book may contain cautions and warnings.

This is an example of a caution statement.
A caution statement describes a situation that could potentially damage your software or equipment.

This is an example of a warning statement.
A warning statement describes a situation that could potentially cause harm to you.

The information in a caution or a warning is provided for your protection. Please read each caution and warning carefully.

**Related Documentation From Texas Instruments**

- **TLC2543C, TLC2543I 12-Bit Analog-to-Digital Converters With Serial Control and 11 Analog Inputs** data sheet (literature number SLAS079C) is included in Appendix A of this book. It contains electrical specifications, available temperature options, general overview of the device, and application information.

- **Microcontroller-Based Data Acquisition Using the TLC2543 12-Bit Serial-Out ADC Application Report** (literature number SLAA012)

- **Data Acquisition Circuits Data Book** (literature number SLAD001)

- **TSL250, TSL251, TSL252 Light-to-Voltage Optical Sensors** data sheet (literature number SOES004C)

- **TLC226x, TLC226xA, TCL226xY Advanced LinCMOS Rail-to-Rail Operational Amplifiers** data sheet (literature number SLOS177)
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The TLC2543 evaluation module (EVM) provides a platform for evaluating the TLC2543 analog-to-digital converter (ADC). For ease of evaluation, the EVM provides for TLC2543 ADC evaluations using an optical sensor, temperature sensor, and variable voltage as inputs. Provisions are available for the user to configure the additional EVM inputs and the system configuration to accommodate other evaluations.

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1.1 Introduction

The TLC2543 evaluation module (TLC2543EVM) consists of a TLC2543 12-bit ADC interface with a TSL250 optical sensor, a transistor-based temperature sensor, a TL1431 voltage reference, a TLC2264 quad op-amp to provide four analog signal buffers, a TL7726 hex clamping circuit for signal over-voltage protection, a TMS370C712 microcontroller, and three TIL311 hex display characters.

The microcontroller reads the user programmed dip switches and communicates with the TLC2543 to select the desired analog input, initiate the conversion process, and transfer the converted data back to the microcontroller. The microcontroller then transforms the data into hex form and transfers the result to the three TIL311 displays. A 74HC244 octal buffer is used as a buffer between the microcontroller and the displays.

A TL7705 power supply voltage monitor provides the reset for the processor at power-on or if the power supply voltage drops below the proper operating level.

Jumper provisions are made to connect the TLC2543 reference voltage to 5-V power for ratiometric measurements or to an absolute voltage provided by a TL1431 voltage reference device.

A connector pattern provides for a user installed interface connector and an uncommitted breadboard area. An external 5-V power supply (4.75 V to 5.25 V at 0.5 A) is required for operation.

The TL7726 hex clamping circuit (VZ1) is connected to inputs IN3 through IN8. The TL7726 clamps an input signal voltage in excess of the power supply voltage level to prevent damage to the semiconductor inputs. Signal voltages below 0 V (ground) are clamped to ground. Signal inputs between 5 V and ground are not affected. The TL7726 provides protection for inputs from incidental transients due to static discharge, excessive signals, etc. Transient current protection is limited to 25 mA.
1.2 Description

This section describes the EVM. A block diagram of the EVM is shown in Figure 1–1.

Figure 1–1. Evaluation Module Block Diagram

The EVM consists of the following:

- 12-bit analog-to-digital converter with:
  - Dedicated optical, temperature, and voltage variable inputs
  - Eight user-configurable inputs
  - User-selectable output for ratiometric or absolute voltage measurements
- Controller with input select and power supply supervisor
- Three-digit hexadecimal display
- User-configurable interface

The EVM functions are described in the following sections.
1.2.1 12-Bit Analog-to-Digital Converter

The TLC2543 is a 12-bit, switched-capacitor, successive-approximation ADC. The device has three control inputs, a chip select, an input-output clock, and a serial data in address input that are interconnected to the microcontroller.

The TLC2543 has an on-chip 14-channel multiplexer that can select any one of 11 inputs or any one of three internal self-test voltages. At the end of conversion, the end-of-conversion (EOC) output goes high indicating to the microcontroller that the conversion is complete.

The microcontroller supplies the serial data address to, and reads the serial digital data from, the TLC2543 ADC.

1.2.1.1 Outputs

At the ADC REF+ and REF– inputs, jumper provisions are made to connect the TLC2543 ADC reference voltage to the 5-V power source that produces ratiometric measurements, or measurements can be made with respect to an absolute voltage provided by a TL1431 voltage reference device.

1.2.1.2 Inputs

The 11 EVM inputs are configured to provide access to the ADC for the following types of conversions:

- Three dedicated inputs that include:
  - An optical sensor
  - A temperature sensor
  - A variable resistor

- Eight additional user-configurable analog inputs:
  - Three buffered inputs by using the TLC2264 operational amplifiers.
  - Five inputs are unbuffered and grounded.

Provisions are made for attaching the eight additional signal lines to the user-supplied interface connector.

1.2.2 Controller

The controller consists of the following:

- The TMS370C712 microcontroller and crystal
- The TL7705B power supply voltage monitor
- The input select switches
1.2.2.1 Microcontroller and Crystal

The microcontroller reads the user-programmed DIP switches and communicates with the TLC2543 to select the desired analog input, initiates the conversion process, and transfers the converted data back to the microcontroller. The microcontroller then transforms the data into hex form and transfers the result to the display.

The crystal generates the clock input for the microcontroller. The microcontroller supplies the TLC2543 ADC clock and the TIL311 display strobes.

1.2.2.2 Power Supply Voltage Monitor

The TL7705B power supply voltage monitor provides a reset for the processor at power-on or when the power supply voltage drops below the proper operating level.

1.2.3 User Interface

Provisions are available for the user to configure the additional EVM inputs and the system configuration to accommodate other evaluations. A connector pattern is provided for the user to install a 16-pin interface connector. A breadboard area is also available on the EVM. The following input and power/ground options are available at the connector interface:

- Three buffered ADC inputs
- Five unbuffered ADC inputs
- Three EVM 5-V power connections
- Two EVM power ground connections
- One EVM signal ground connection

Terminals for an external 5-V power supply are provided. An external 5-V power supply (4.75 V to 5.25 V at 0.5 A) is required for operation.

1.2.4 Display

The microcontroller decodes the 12-bit ADC data into hexadecimal three-digit values which activate the three hexadecimal displays.

Buffers are used between the microcontroller and the display data input ports and blanking inputs. The three display latch strobes are driven directly from the microcontroller I/O port.
Chapter 2

Hardware Description and Operation

This chapter contains descriptions of the hardware and operation of the TLC2543EVM. This chapter includes the following topics:

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</tr>
</tbody>
</table>
2.1 Setup and Operation

Figure 2–1, a schematic diagram of the EVM, identifies the EVM components and the setup and operating procedures.

Figure 2–1. EVM Board Schematic
Figure 2–1. EVM Board Schematic (Continued)
2.1.1 Power Supply Terminals

The power supply terminals (J2) on the EVM, see Figure 2–1, should be connected to a regulated 4.75-V to 5.25-V power supply capable of providing at least 0.5 A.

This evaluation module is designed to have power supplied from an external regulated 5-V power supply. No form of power supply regulation is included on the EVM. Damage to the components can and probably will occur if the voltage exceeds the maximum specified level. Under voltage can cause improper operation.

When the power supply is switched on, the microcontroller is initialized and the displays flash to indicate proper operation. The displays then show the 2- or 3-digit hex value of the voltage generated by the TSL250 optical sensor. The value on the displays varies with the intensity of the light striking the TSL250 sensor (see section 2.3.1, Optical Sensor).

2.1.2 Input/Output Select Switches

The INPUT SELECT switch (S1) sets the binary address (LSB on the right) which selects the desired TLC2543 input (see subsection 2.1.3, Input Select Switch).

The EVM is shipped with the settings listed in Table 2–1:

Table 2–1. EVM Default Settings

<table>
<thead>
<tr>
<th>Function</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input select switch (S1)</td>
<td>0000 hex (optical sensor selected)</td>
</tr>
<tr>
<td>Reference select jumper (JP9)</td>
<td>REF V</td>
</tr>
<tr>
<td>REF– jumper (JP10)</td>
<td>Shorted</td>
</tr>
</tbody>
</table>

Note:
The input and output jumpers and the REF– jumper on the EVM are formed by a top-side copper trace on the PCB between two plated through-holes. If desired, the trace can be carefully cut to remove the jumper. The two-through-holes allow the user to restore the jumper with a wire or connector.

2.1.3 Input Select Switch

The four-position DIP switch (S1) labeled INPUT SELECT allows the user to select the desired analog input of the TLC2543 ADC. The software program then uses the onboard SPI interface to communicate with the TLC2543 and make the hexadecimal conversions.
2.1.3.1 **Binary-to-Hexadecimal Conversion**

The bits are read into the processor and output on the three LED displays approximately every 0.5 second. The switch is treated as a hex address command (MSB on left, LSB on right) as listed in Table 2–2:

**Table 2–2. Input Select Switch Descriptions**

<table>
<thead>
<tr>
<th>Hex</th>
<th>Binary</th>
<th>Function Selected</th>
<th>Typical Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>0h</td>
<td>0000</td>
<td>Optical sensor input</td>
<td>User-controlled light intensity</td>
</tr>
<tr>
<td>1h</td>
<td>0001</td>
<td>Temperature sensor input</td>
<td>588h + temperature change</td>
</tr>
<tr>
<td>2h</td>
<td>0010</td>
<td>Potentiometer input</td>
<td>User adjusted</td>
</tr>
<tr>
<td>3h</td>
<td>0011</td>
<td>IN3 buffer input</td>
<td>000h or user input</td>
</tr>
<tr>
<td>4h</td>
<td>0100</td>
<td>IN4 buffer input</td>
<td>000h or user input</td>
</tr>
<tr>
<td>5h</td>
<td>0101</td>
<td>IN5 buffer input</td>
<td>000h or user input</td>
</tr>
<tr>
<td>6h–Ah</td>
<td>0110–1010</td>
<td>IN6 through IN10 inputs</td>
<td>000h or user input</td>
</tr>
<tr>
<td>Bh</td>
<td>1011</td>
<td>(V_{\text{ref}}) input/2 test</td>
<td>800h</td>
</tr>
<tr>
<td>Ch</td>
<td>1100</td>
<td>(-V_{\text{ref}}) input (ground) test</td>
<td>000h</td>
</tr>
<tr>
<td>Dh</td>
<td>1101</td>
<td>(V_{\text{ref}}) input test</td>
<td>FFFh</td>
</tr>
<tr>
<td>Eh</td>
<td>1110</td>
<td>Enter power-down mode</td>
<td>Display blank</td>
</tr>
<tr>
<td>Fh</td>
<td>1111</td>
<td>Fast conversion rate on IN4 input</td>
<td>User input</td>
</tr>
</tbody>
</table>

**Note:** Inputs IN3 through IN10 are made available to a user-supplied connector (see section 2.1.4, *Interface Connector Provisions*).

2.1.3.2 **Fast Conversion Rate**

When the INPUT SELECT switch is set to Fh, the EVM operates in a fast conversion rate mode. In this mode, the conversion rate is approximately 30k conversions per second from the IN4 input. The displays are updated once every 20 conversions.
2.1.4 Interface Connector Provisions

A PCB footprint is provided for a user-supplied connector to allow easy application of external analog signals. The hole pattern interface connector provided at J1, see Figure 2–2, accepts a standard 8-by-2 set of header posts (such as an AMP 87215–5 or MOLEX 10–89–1161) that can be soldered in place. This arrangement accommodates several different styles of connectors so the user can select the one that best satisfies the system requirements.

Figure 2–2. Interface Connector Hole Pattern

```
J1
1  3  5  7  9 11 13 15
2  4  6  8 10 12 14 16
```

Table 2–3 describes the hole-pattern mapping to circuit functions.

<table>
<thead>
<tr>
<th>Hole</th>
<th>Circuit Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NC</td>
</tr>
<tr>
<td>2</td>
<td>NC</td>
</tr>
<tr>
<td>3</td>
<td>IN3 input (buffered with 1× gain)</td>
</tr>
<tr>
<td>4</td>
<td>IN4 input (buffered with 2× gain)</td>
</tr>
<tr>
<td>5</td>
<td>IN5 input (buffered with 2× gain)</td>
</tr>
<tr>
<td>6</td>
<td>IN6 input</td>
</tr>
<tr>
<td>7</td>
<td>IN7 input</td>
</tr>
<tr>
<td>8</td>
<td>IN8 input</td>
</tr>
<tr>
<td>9</td>
<td>IN9 input</td>
</tr>
<tr>
<td>10</td>
<td>IN10 input</td>
</tr>
<tr>
<td>11</td>
<td>5 V</td>
</tr>
<tr>
<td>12</td>
<td>Signal ground (see Note)</td>
</tr>
<tr>
<td>13</td>
<td>5 V</td>
</tr>
<tr>
<td>14</td>
<td>Power ground</td>
</tr>
<tr>
<td>15</td>
<td>5 V</td>
</tr>
<tr>
<td>16</td>
<td>Power ground</td>
</tr>
</tbody>
</table>

**Note:** Hole 12 can be used as a signal ground return to avoid the higher current ground return paths that are associated with a power supply ground.
2.2 Microcontroller and Interface

This section provides an overview and describes the operation of the microcontroller and interface function.

2.2.1 Overview

The TLC2543EVM uses a TI TMS370C712 microcontroller to interface with the TLC2543 ADC. The program reads the four-position INPUT SELECT DIP switch to determine which input is selected to be digitized. The program then uses the serial peripheral interface (SPI) to communicate with the TLC2543. Sixteen bits of data (12 significant bits and 4 fill bits) are read into the processor and output on the three LED displays approximately every 0.5 second.

A fast mode can also be selected with the INPUT SELECT switch. In this mode, channel four is selected as input and 20 samples are taken at about a 30-kHz rate, data is converted and displayed, and the process is repeated until another input is selected with the switch. A power-down mode, which places the TLC2543 in a power-down mode and blanks the display, can also be selected.

2.2.2 Operation

The TMS370C712 microcontroller (U4) samples the status of the INPUT SELECT switch on ports A4–A7. This sample data, which is sent to the TLC2543 ADC through the SPI ports (SPICLK, SPISIM0, and SPISOMI) determines the specific multiplexer input that is converted. The microcontroller then reads back the converted 12 bits and decodes the data into hexadecimal three-digit values. The hexadecimal data is transferred to the three hexadecimal displays, U7, U8, and U9. Five sections of the 74HC244 octal buffer are used to drive the common-bused TTL inputs of the displays.

For all INPUT SELECT positions except Fh, the microcontroller instructs the TLC2543 ADC to perform the analog-to-digital conversions and display the results at a rate of approximately 2 conversions per second. When the INPUT SELECT position is Fh, the microcontroller selects input IN4 and the conversions from the ADC are at a rate of approximately 30-k conversions per second (see section 2.1.3.2, Fast Conversion Rate).

Notes:
The following information applies to the TMS370C712 SPI protocol to the TLC2543.
The TLC2543 strobes in the command data bits from the microcontroller on the DIN port at the rising edge of the clock pulse on the I/O CLK terminal. The TMS370C712 generates a clock rising edge on the SPICLK port, and at that time while conforming to the SPI interface requirements, the data output on the SPISIM0 port changes to reflect the next serial bit to be transferred.
Notes: Continued

Therefore, if the SPICLK output is connected directly to the TLC2543 ADC I/O CLK input, the required data setup time for the data to be present before a rising clock edge is applied cannot be less than 100 ns (see the TLC2543 data sheet). To solve this race condition, a resistor (R24) and capacitor (C21) are provided to delay the rising clock edge. One buffer section of the 74HC244 octal buffer (U6) is used to buffer the delayed clock signal. If only one TLC2543 ADC is being used (as with this EVM), the buffer is not usually required. However, if several TLC2543 devices are being driven in a bus configuration, this buffer is required to provide a proper clock signal into the additional capacitance.

2.2.3 Power Supply Supervisor

The TL7705 power supply supervisor, U5, (see Figure 2–1) monitors the power supply voltage. When power is first applied, a microprocessor reset is held until the power supply voltage exceeds 4.55 V (nominal). The reset is then released and the microprocessor begins operation.

If the power supply voltage falls below 4.55 V during normal operation, a reset is activated.
2.3 Sensor Inputs

The EVM inputs are configured to provide access to the ADC as outlined in Section 1.2.1.2. These inputs are discussed in more detail below.

2.3.1 Optical Sensor

The TSL250 (U1) optical sensor is connected to the AIN0 multiplexer analog input port of the TLC2543 ADC. This sensor converts light intensity to an output voltage ranging from less than 10 mV (dark) to about 3.5 V (at 2 mW/sq cm illumination intensity).

The output of the optical sensor can be varied by placing an object such as a dark-colored plastic marker pen cap over the sensor.

A practical application such as sorting can be demonstrated by holding similar objects of differing shades within the optical viewing range of the sensor (under a uniform intensity light) and noting the displayed values. A simple optical hood to mask ambient light (e.g., drill a hole in the side of the marker pen cap) provides more uniform results.

Note:
Office light generated by typical artificial lighting contains high ac line frequency intensity variations not usually perceived by the human eye. These variations are detected by the optical sensor. Since the ADC is commanded to make measurements at random times with respect to the ac line frequency, the converted values appear to be unstable in the lower order bits, even though each individual measurement is accurate. This line frequency light intensity variation can be minimized by using dc power to drive the dominate light source (light-emitting diodes work well) in addition to shielding the sensor from the ac-driven room lighting.

An extension of the sorting concept yields a simple color-sorting sensor system. This system requires three optical sensors, each masked by a red, blue, or green optical filter. The individual readings from the three sensors can then be calibrated to the specific color of the object to be identified. For repeatable results, the intensity and color content of the illuminating light source must be uniform.

2.3.2 Temperature Sensor

When a single transistor and the 12-bit A/D conversion range of the TLC2543 ADC are used, the following occurs:

- A simple temperature sensor is generated
- The textbook temperature variation of a transistor base-emitter junction
- The dc temperature instability of a simple 1-transistor amplifier

The 2N2222A transistor (Q1) is connected in a classic feedback amplifier configuration that forces the collector voltage to a base-emitter junction voltage of 2 $V_{be}$. The base-emitter junction (essentially a forward-biased diode) voltage is about 0.7 V at room temperature (25 °C) and has a temperature
variation of about –2.2 mV/°C. Therefore, at room temperature the collector voltage is approximately 1.4 V with a decrease of approximately 4.4 mV for each degree of temperature increase.

If the REF SELECT jumper is set to the onboard reference (REF V) position, the conversion reference is set to approximately 4096 mV or 4.1 V. This setting allows the display to decrement approximately 1 count for each mV or about 4 counts per °C of temperature increase.

If the ambient room temperature is approximately 25°C and human body temperature is approximately 38°C, the display should reduce about 52 counts when the transistor is held firmly between two fingers. (For an exact analysis, exact transistor characteristics, absolute reference voltage levels, and exact room and finger temperatures would have to be taken into account.)

### 2.3.3 Voltage Variable Input (Potentiometer)

The IN2 input is controlled by a potentiometer (R13). One section of the TLC2264 (U2) serves as a buffer/amplifier for the AIN2 TLC2543 input port. When the potentiometer is adjusted over its range, the input voltage changes from 0 V to $V_{CC}/2$. Since the buffer/amplifier has a gain of 2, the input to the TLC2543 ADC port varies from 0 V to $V_{CC}$.

For ratiometric measurements, the REF SELECT jumper should be set to the $V_{CC}$ position. Then the TLC2543 ADC reference becomes $V_{CC}$ and all A/D conversions are made relative to the value of $V_{CC}$. The potentiometer output voltage, due to its connection, is also relative to $V_{CC}$. An A/D conversion of that voltage yields a value proportional to the setting of the potentiometer and independent of the power supply voltage.

### 2.3.4 Buffered User Inputs

The IN3 input is connected to the TLC2543 input port through unity gain configured buffer/amplifier (one section of the TLC2264, U2). Although providing unity gain (gain = 1), the input signal can only be within approximately 1.5 V (see the common-mode input-voltage range specifications of the TLC2264 ADC) of the power supply voltage to maintain predictable operation. As long as the power supply voltage to the TLC2264 remains at 5 V, this restricts the usable signal input voltage range from 0 V to 3.5 V; however, this range can be acceptable for some input level requirements.

The input impedance is dictated by the 10-kΩ value of resistor R14 and can be changed to almost any suitable value due to the extremely high input impedance of the TLC2264.

Inputs IN4 and IN5 are connected to the TLC2543 ADC input ports, each through a buffer stage of the TLC2264, and each with a gain of 2. The full output voltage swing of 0 V to 5 V to the ADC inputs is achieved with signal inputs of 0 V to 2.5 V as listed in 2–4.
Table 2–4. Buffered User Input Descriptions

<table>
<thead>
<tr>
<th>Input</th>
<th>Gain</th>
<th>Unbuffered</th>
<th>Input Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN3</td>
<td>×1</td>
<td>N</td>
<td>0 V – 3.5 V (input to ADC is 3.5/5 of full scale)</td>
</tr>
<tr>
<td>IN4</td>
<td>×2</td>
<td>N</td>
<td>0 V – 2.5 V</td>
</tr>
<tr>
<td>IN5</td>
<td>×2</td>
<td>N</td>
<td>0 V – 2.5 V</td>
</tr>
<tr>
<td>IN6</td>
<td>Y</td>
<td></td>
<td>0 V – 5 V</td>
</tr>
<tr>
<td>IN7</td>
<td>Y</td>
<td></td>
<td>0 V – 5 V</td>
</tr>
<tr>
<td>IN8</td>
<td>Y</td>
<td></td>
<td>0 V – 5 V</td>
</tr>
<tr>
<td>IN9</td>
<td>Y</td>
<td></td>
<td>0 V – 5 V</td>
</tr>
<tr>
<td>IN10</td>
<td>Y</td>
<td></td>
<td>0 V – 5 V</td>
</tr>
</tbody>
</table>

2.3.5 Unbuffered Inputs

The IN6–IN10 inputs are connected to ground by the top-side circuit board etch jumpers, JP1, JP2, JP3, JP12, and JP11, respectively. Any etch jumper can be removed by carefully cutting the copper trace between the feed-through holes at the JP marking, allowing that input to be connected to an external signal.

When these unbuffered inputs are used, the TLC2543 ADC requires a low source impedance (see Section 2.7, Driving the Input of a Switched-Capacitor ADC) and input voltage range of 0 V to 5 V to produce a zero-to-full-scale digital output. Ensure that the signal grounds are not improperly connected to the high-current power supply grounds (see Section 2.5, Grounding Considerations).

2.3.6 Input Voltage Clamp

The TL7726 hex clamping circuit (VZ1) is connected to inputs IN3 through IN8. The TL7726 clamps an input signal voltage in excess of the power supply voltage level to prevent damage to the semiconductor inputs. Signal voltages below 0 V (ground) are clamped to ground. Signal inputs between 5 V and ground are not affected. The TL7726 provides protection for inputs from incidental transients due to static discharge, excessive signals, etc. Transient current protection is limited to 25 mA.
2.4 Input Reference Voltage Select

The REF SELECT jumper allows ratiometric measurements (jumper set to \(V_{CC}\)) or allows absolute measurements (jumper set to REF V) relative to a voltage reference established by the TL1431 (D1). This voltage reference is programmed by resistors R22 and R23 to a voltage level of approximately 4.1 V.

2.4.1 Ratiometric Measurements

Ratiometric measurements are measurements made relative to the 5-V power supply voltage. If a sensor or input signal voltage is used that varies proportionally to the 5-V power supply voltage (such as the potentiometer R13), then the signal becomes a ratio of the absolute value of the power supply voltage. Therefore, when the reference voltage is connected to 5 V (REF SELECT jumper position at \(V_{CC}\)), the TLC2543 tracks the power supply voltage and provides a converted result independent of the power supply voltage variations.

2.4.2 Absolute Measurements

Absolute measurements are required when the input analog signal does not change with the power supply voltage. The optical and temperature sensors are in this category. For these sensors, the REF SELECT jumper is set to the REF V position.
2.5 Grounding Considerations

This section explains the grounding techniques that should be considered when designing or configuring systems using analog devices such as the ADC.

2.5.1 Grounding Problems

When designing analog circuits that share a ground with digital and high current power supplies, the voltage drop along the high current paths must be taken into account. This voltage drop is a result of the current flowing through the greater-than-zero resistance of the current path, and/or high frequency current transients flowing through the greater-than-zero inductance of a current path.

If the signal ground is connected to the power supply ground at a location where excessive power currents may flow through the analog ground, the voltage drop is injected into the signal ground and appears as part of the signal, thus causing an error.

2.5.2 Using a Single Ground Point

For low frequency circuits, usually below 100 kHz, the solution is to establish a single ground point on the PC board and connect all grounds individually to that point (the EVM single ground point is at the GND terminal of the power supply connector). By using this method, currents flowing along any one path to ground do not inject error voltages in any other ground path.

2.5.3 A Practical Approach

As a practical implementation, however, it may not be reasonable to run a separate ground trace for each component that connects to ground. Therefore, the next best approach is to group the higher current grounds (such as the power supply and digital grounds) together and run them to the central PC board ground point, while still maintaining separate ground paths for the analog grounds.

An analysis of current flow paths within the analog section gives an indication of which grounded components could be grouped together into a common ground path and which should be kept separate. For instance, on the EVM, it would be reasonable to use a common path for the TLC2543 REF– terminal, the TL1431 anode, and the grounded side of R23. This is because the only significant current flow is through the TL1431 (approximately 1 mA) and is not enough to cause a significant error. (A 1/2 LSB error at a reference voltage of 4.1 V would be approximately 0.5 mV, so the ground trace would have to be in excess of 0.5 Ω to cause such an error.)

If all of the input signals are low current, such as the optical sensor (approximately 2 mA), the temperature sensor (approximately 1 mA), and the potentiometer (approximately 0.25 mA), it may be reasonable to use a common ground trace. (As always, wider trace widths are desirable to keep the resistance low.) Whenever high currents are associated with any input signal, always use a separate PC board trace directly to the central ground point location.
Grounding Considerations

Even though the operating current of the TLC2543 is low (2.5 mA maximum), some high speed current transients due to the internal digital switching are present and a separate ground trace is reasonable.

**Note:**
Keep the power supply decoupling capacitor as close as possible to the supply pins using a separate ground trace for the decoupling capacitor and the TLC2543 ground pin.

If free area is available, or if the PC board is multilayer, a large ground plane may be acceptable to connect all of the analog side ground connections, providing that any one signal ground connection is not carrying a large current. That ground plane should be connected directly to the central ground point without touching any of the digital or power supply ground locations along its path.
2.6 Power Considerations

Analyzing the distribution of the digital and analog 5-V current paths on the PCB in a similar manner to the grounds is also a good practice. The designated central power point location is the 5-V terminal of the power supply connector (J2) on the EVM board.
2.7 Driving the Input of a Switched-Capacitor ADC

When applying an analog signal to the input of a switched-capacitor ADC such as the TLC2543, care must be taken to provide a low enough impedance to the input terminal to charge the internal capacitor (see Figure 2–3) enough for an accurate conversion during the sampling phase of the converter. The sampling time depends on the period of the I/O clock rate being used to drive the converter and the number of transfer bits commanded. With the maximum I/O clock frequency of 4.1 MHz and a 12-bit transfer mode, the TLC2543 uses eight clock cycles (or approximately 2 μs) for the sampling time.

![Figure 2–3. Equivalent Input Circuit](image)

The input equivalent circuit of the TLC2543 looks like a series resistance and a capacitor to ground during sampling and an open circuit during conversion.

For accurate operation the input capacitor must be charged to the required accuracy of 1/2 LSB (or more, depending on the required system error budget) during the sampling phase of the ADC cycle.

The voltage on capacitor C1 is given by:

\[ V_C = V_S \left(1 - e^{-t/TC}\right) \]  

Where:

\[ TC = \text{the time constant } C_1(R_S + R_1) \]

The final voltage value of \( V_C \) within 1/2 LSB of \( V_S \) is given by:

\[ V_C \left(1/2 \text{ LSB}\right) = V_S - V_S/2^n + 1 \]  

Where:

\[ n = \text{the resolution of the converter.} \]

Equating equation 1 to equation 2, then:

\[ V_S - V_S/2^n + 1 = V_S \left(1 - e^{-t/TC}\right) \]

Therefore, the charging time in terms of the circuit time constants is:

\[ t \left(1/2 \text{ LSB}\right) = TC \ln\left(2^n + 1\right) \]  

For a 12-bit converter, this would be:

\[ t_S = TC \times \ln(8192) = 9TC \]

The internal capacitance for the TLC2543 is 60 pF maximum and the internal series resistance is 1 kΩ. Therefore, with an I/O clock at 4.1 MHz and a 12-bit
transfer mode (sample period = 2 μs), the time constant should be no more than:

\[ \frac{1}{9} \times 2 \, \mu s = 0.22 \, \mu s \]  

(6)

Therefore,

\[ C_1(R_S + R_1) = 0.22 \, \mu s \]  

(7)

So,

\[ (R_S + R_1) = 3.67 \, k\Omega \]  

(8)

Since \( R_S = 1 \, k\Omega \), the source impedance should be less than 2.67 kΩ to stay within 1/2 LSB error. Good design practice dictates that the source impedance be as low as possible, such as the output of an op-amp. However, in an application where fast conversion time is not critical, slow I/O clock rates can allow the driving source impedance to be relatively large.
This chapter contains illustrations of the board layout and layers.

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<td>3.2 Board Layers</td>
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</tr>
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</table>
3.1 Board Layout

Figure 3–1. TLC2543EVM Board Layout
3.2 Board Layers

Figure 3–2. Solder Mask

Figure 3–3. Layer 1
Figure 3–4. Layer 2 (Bottom Side)

Figure 3–5. Drill Template
Table 4–1 lists and describes the TLC2543 EVM parts.
# Table 4–1. Part Descriptions

<table>
<thead>
<tr>
<th>Description</th>
<th>Reference</th>
<th>Quantity</th>
<th>Value/Type Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitors</td>
<td>C1</td>
<td>1</td>
<td>100 μF, 16 V aluminum</td>
</tr>
<tr>
<td></td>
<td>C2, C3, C4, C5, C7, C8, C12, C13, C14, C15, C16, C17, C18, C19</td>
<td>14</td>
<td>0.1 μF ceramic, Z5U, 0.2-inch</td>
</tr>
<tr>
<td></td>
<td>C6, C9,</td>
<td>2</td>
<td>10 μF, 10 V tantalum, 0.2-inch</td>
</tr>
<tr>
<td></td>
<td>C10, C11</td>
<td>2</td>
<td>15 pF ceramic, NPO, 0.2-inch</td>
</tr>
<tr>
<td>Precision programmable reference</td>
<td>D1</td>
<td>1</td>
<td>TL1431CLP</td>
</tr>
<tr>
<td>Power supply terminals</td>
<td>J2</td>
<td>1</td>
<td>Terminal block, 2-pos, 5-mm, side entry (OST ED1601)</td>
</tr>
<tr>
<td>Header and shorting jumper</td>
<td>JP9</td>
<td>1</td>
<td>3-pin header</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2-pin jumper</td>
</tr>
<tr>
<td>Temperature sensor</td>
<td>Q1</td>
<td>1</td>
<td>2N2222A (T0–18 metal can)</td>
</tr>
<tr>
<td>Resistors</td>
<td>R1, R2, R3, R4, R5, R10, R11, R12, R14, R15, R16, R17, R18, R19, R20, R23</td>
<td>16</td>
<td>10 kΩ, 1%, 0.25-W</td>
</tr>
<tr>
<td></td>
<td>R6</td>
<td>1</td>
<td>499 Ω</td>
</tr>
<tr>
<td></td>
<td>R7, R8</td>
<td>2</td>
<td>49.9 kΩ</td>
</tr>
<tr>
<td></td>
<td>R9</td>
<td>1</td>
<td>4.99 kΩ</td>
</tr>
<tr>
<td></td>
<td>R21</td>
<td>1</td>
<td>1 kΩ</td>
</tr>
<tr>
<td></td>
<td>R22</td>
<td>1</td>
<td>6.34 kΩ</td>
</tr>
<tr>
<td></td>
<td>R13</td>
<td>1</td>
<td>10 kΩ potentiometer, single turn, top adj, 3/8-inch sq (Bourns 3386 P)</td>
</tr>
<tr>
<td>Input select switch</td>
<td>S1</td>
<td>1</td>
<td>DIP, 4-pos, gold</td>
</tr>
<tr>
<td>Optical sensor</td>
<td>U1</td>
<td>1</td>
<td>TSL251</td>
</tr>
<tr>
<td>Rail-to-rail operational amplifiers</td>
<td>U2</td>
<td>1</td>
<td>TLC2264</td>
</tr>
<tr>
<td>12-bit analog-to-digital converter</td>
<td>U3</td>
<td>1</td>
<td>TLC2543</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>U4</td>
<td>1</td>
<td>TMS370C712</td>
</tr>
<tr>
<td>Supply voltage supervisor</td>
<td>U5</td>
<td>1</td>
<td>TL7705B</td>
</tr>
<tr>
<td>Octal buffer</td>
<td>U6</td>
<td>1</td>
<td>74HC244</td>
</tr>
<tr>
<td>Hexadecimal display with logic</td>
<td>U7, U8, U9</td>
<td>3</td>
<td>TIL311</td>
</tr>
<tr>
<td>Hex clamping circuits</td>
<td>VZ1</td>
<td>1</td>
<td>TL7726</td>
</tr>
<tr>
<td>Crystal</td>
<td>Y1</td>
<td>1</td>
<td>12 MHz, HC–49/μs</td>
</tr>
<tr>
<td>PCB</td>
<td></td>
<td>1</td>
<td>TLC2543 EVM</td>
</tr>
</tbody>
</table>
Software Program and Flow Charts

This chapter lists the software program and provides flow charts for the program and each of the programs subroutines.

The following topics are covered:

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5.1 Software Program

TMS370 Macro Assembler      Version 5.20     Thu Aug 17 17:20:54 1995
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adc_evm.asm                                                          PAGE    1

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
1                ; TLC2543 EVALUATION MODULE PROGRAM
2                ; VERSION 1.2  8/17/95
3                ; THIS PROGRAM READS A FOUR-POSITION DIP
4                ; SWITCH WHICH IS USED TO SELECT THE INPUT
5                ; SIGNAL CHANNEL TO THE ADC.  THE PROGRAM
6                ; THEN SELECTS THIS CHANNEL ON THE ADC AND
7                ; CONVERTS THE ANALOG INPUT TO A 12-BIT
8                ; HEX NUMBER AND OUTPUTS THE RESULTS ON
9                ; 3 7-SEGMENT DISPLAYS. POSITIONS ARE ALSO
10               ; PROVIDED TO PUT THE ADC IN A POWER-DOWN
11               ; MODE AND A FAST MODE (APPROX 26 kHz RATE).
12               ;
13               ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
14               ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
15                ;
16                ; SYSTEM EQUATES
17                ;
18                ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
19                ;
20                ; SERIAL PERIPHERAL INTERFACE (SPI) REGISTERS
21                ;
22                ; 0030 SPICCR .EQU P030 ;SPI CONFIG REG
23                ; 0031 SPICTRL .EQU P031 ;SPI OPERATION CONTROL REG
24                ; 0037 SPIBUF .EQU P037 ;SPI INPUT BUFFER
25                ; 0039 SPIDAT .EQU P039 ;SPI SERIAL DATA REG
26                ; 003d SPIPC1 .EQU P03d ;SPI PORT CONTROL REG1
27                ; 003e SPIPC2 .EQU P03E ;SPI PORT CONTROL REG2
28                ; 003f SPIPRI .EQU P03F ;SPI INTERRUPT CONTROL REG
29                ;
30                ; PORT A AND D REGISTERS
31                ;
32                ; 0021 APORT2 .EQU P021 ;PORT A CONTROL REG
33                ; 0022 ADATA .EQU P022 ;PORT A DATA
34                ; 0023 ADIR .EQU P023 ;PORT A DIRECTION
35                ; 002c DPORT1 .EQU P02c ;PORT D CONTROL REG1
36                ; 002d DPORT2 .EQU P02d ;PORT D CONTROL REG 2
37                ; 002e DDATA .EQU P02E ;PORT D DATA
38                ; 002f DDIR .EQU P02F ;PORT D DIRECTION
39                ;
40                ; TIMER 1 DEFINITIONS
41                ;
42                ; 0040 TC1CTR1 .EQU P040 ;MSB OF COUNTER
43                ; 0041 TC1CTR2 .EQU P041 ;LSB OF COUNTER
44                ; 0042 TC11 .EQU P042 ;MSB OF COMPARE REGISTER
45                ; 0043 TC12 .EQU P043 ;LSB OF COMPARE REGISTER
46                ; 0049 TC1CTL1 .EQU P049 ;TIMER 1 CONTROL REG 1
47                ; 004a TC1CTL2 .EQU P04A ;TIMER 1 CONTROL REG 2
48                ; 004b TC1CTL3 .EQU P04B ;TIMER 1 CONTROL REG 3
49                ;
50                ; BIT DEFINITIONS
51                ;
52                ;
53                ;
54                ;
55                ;
56        2e        CSBIT  .DBIT   3,DDATA   ;ADC CHIP SELECT BIT
57        31        SPIF   .DBIT   6,SPICTL  ;SPI INTR FLAF
58        2e        DOUT1  .DBIT   5,DDATA   ;STROBE FOR DISPLAY 1
59        2e        DOUT2  .DBIT   6,DDATA   ;STROBE FOR DISPLAY 2
60        2e        DOUT3  .DBIT   7,DDATA   ;STROBE FOR DISPLAY 3
61        2e        DBLANK .DBIT   4,DDATA   ;BLANK STROBE
62        4a        RST    .DBIT   0,T1CTL2  ;SW TIMER RESET
63        4b        TOUT   .DBIT   5,T1CTL3  ;TIMER 1 TIME OUT
64        ;
65        ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
66        ;
67 6000                     .TEXT   6000H   ;START OF PROGRAM
68        ;
69        ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
70        ;
71        ; MAIN PROGRAM
72        ;
73 6000  5260      START   MOV     #60H,B
74 6002   fd                LDSP            ;SET STACK POINTER TO 60H
75 6003  '8e6014            CALL    INIT    ;INITIALIZE SYSTEM
76        ;
77 6006  '8e6056    LOOP    CALL    READSW  ;READ INPUT DIP SWITCH
78 6009  '8e60ed            CALL    ADC     ;DIGITIZE INPUT
79 600c  '8e614d            CALL    DISPLAY ;DISPLAY VALUE
80 600f  '8e6126            CALL    DELAY   ;DELAY .5 SEC
81 6012  '00f2              JMP     LOOP
82        ;
83        ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
84        ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
85        ;
86        ; INIT
87        ;
88        ; THIS ROUTINE INITIALIZES PORTS A AND
89        ; D, SETS UP THE SPI, AND INITIALIZES
90        ; THE DISPLAYS BY FLASHING 8 AND 0 THREE
91        ; TIMES.
92        ;
93 6014   f70021    INIT    MOV     #0,APORT2  ;SET PORT A TO I/O
94 6017   f70f23            MOV     #0FH,ADIR  ;SET A4–A7=INPUT, A0–A3 = OUTPUT
95 601a   f7002c            MOV     #0,DPORT1  ;SET PORT D TO I/O
96 601d   f7002d            MOV     #0,DPORT2
97 6020   f7f2f2f            MOV  #0F2H,DDIR ;SET D3–D7 OUTPUTS
98        ;
99 6023   f78030            MOV  #80H,SPICCR ;INIT SPI
100 6026  f70730            MOV  #07H,SPICCR ;SET CLOCK, 8BIT CHAR LEN
101 6029  f7033d            MOV  #03H,SPIPC1 ;SET SPI CLK TO OUTPUT
102 602c  f7223e            MOV  #22H,SPIPC2 ;SET SPI SOMI AND SPI SIMO TO SPI DATA
103        ;
104 602f  720019            MOV  #0,R25     ;CLR CHANNEL REGS
105 6032  72001d            MOV  #0,R29
106        ;
107        ; FLASH DISPLAY
108        ;
109 6035  720314            MOV  #03,R20  ;SET LOOP CTR TO 3 CYCLES
110 6038  2208            MOV  #08H,A    ;SET DISPLAY REGS TO 8
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111 603a   d01a              MOV     A,R26
112 603c   d01b              MOV     A,R27
113 603e   d01c              MOV     A,R28
114 6040   '8e614d    LOOP1   CALL    DISPLAY
115 6043   720218            MOV     #02H,R24   ;SET DELAY TO .5 SEC
116 6046   '8e6126            CALL    DELAY
117 6049   a4102e            SBIT1   DBLANK     ;BLANK DISPLAY
118 604c   '8e6126            CALL    DELAY
119 604f   a3ef2e            SBIT0   DBLANK     ;TURN OFF BLANK
120 6052   'da14eb            DJNZ    R20,LOOP1  ;JMP BACK IF NOT DONE
121 6055   f9                RTS
122                  ;
123                  ;;;;;;;;;;;;;;;;;;;;;;;;
124                  ;;;;;;;;;;;;;;;;;;;;;;;;
125                  ;
126                  ;;READSW
127                  ;
128                  ;;THIS ROUTINE READS THE 4 POSITION DIP
129                  ;;SWITCH FOR THE CHANNEL NUMBER AND SAVES
130                  ;;IT IN R29. IF 0EH IS SELECTED THE ADC
131                  ;;IS PLACED IN A POWER DOWN MODE. IF 0FH
132                  ;;IS SELECTED THE INPUT ON CHANNEL 4 IS
133                  ;;CONVERTED IN FAST MODE. ADC CHANNEL NUMBER
134                  ;;IS STORED IN R25.
135                  ;
136                  ;
137 6056   8022      READSW  MOV     ADATA,A ;READ SWITCHES
138 6058   b7                SWAP    A       ;SWAP NIBBLES
139 6059   230f              AND     #0FH,A
140 605b   1d1d              CMP     R29,A
141 605d  '0601              JNE     READ1   ;JMP IF ADC INPUT CHANGED
142 605f   f9                RTS
143                  ;
144                  ; ADC INPUT CHANGED - WAIT FOR COMPLETE
145                  ;
146 6060   d01d      READ1   MOV     A,R29   ;SAVE IT
147 6062   720318            MOV     #03,R24 ;SET DELAY FLAG TO 2 SEC
148 6065   '8e6126            CALL    DELAY
149 6068   8022            MOV     ADATA,A ;CHECK AGAIN
150 606a   b7                SWAP    A
151 606b   230f              AND     #0FH,A
152 606d   1d1d              CMP     R29,A
153 606f   '06ef              JNE     READ1
154                  ;
155                  ;;SEE IF POWER DOWM MODE
156                  ;
157 6071   7d0e1d            CMP     #0EH,R29
158 6074   '061b              JNE     READ2   ;JMP IF NOT POWER DOWN
159 6076   a4102e            SBIT1   DBLANK     ;BLANK DISPLAY
160 6079   a3f72e            SBIT0   CSBIT     ;ENABLE ADC
161 607c   f70631            MOV     #06H,SPICTL
162 607f   f7ec39            MOV     #0ECH,SPIDAT
163 6082   8022      READ3   MOV     ADATA,A ;WAIT FOR CHANGE
164 6084   b7                SWAP    A
165 6085   230f              AND     #0FH,A
ADC EVM

166 6087 * 4d001d      CMP A,R29
167 608a '02f6            JEQ READ3
168 608c a3ef2e      SBITO DBLANK ;CLEAR BLANK
169 608f '00cf            JMP READ1

170                      ;SEE IF FAST MODE
171                      ;
172                      ;
173 6091 7d0f1d    READ2    CMP #0FH,R29 ;IS IT FAST MODE
174 6094 '0650            JNE READ4
175 6096 a3f72e    RLOOP1   SBITO CSBIT ;ENABLE ADC
176 6099 720419    MOV #04H,R25 ;CHANNEL 4 - FAST MODE
177 609c 224c      MOV #4CH,A ;CHANNEL 4,16BITS,MSB 1ST
178 609e 721414    MOV #20,R20 ;DO 20 FAST THEN UPDATE
179 60a1 f70631    MOV #06H,SPICTL
180 60a4 2139    RLOOP2   MOV A,SPIDAT
181 60a6 'a74031fc RFLG1   JBIT0   SPIF,RFLG1 ;WAIT FOR DATA
182 60aa a21537    MOV SPIBUF,R21
183 60ad 2139    MOV A,SPIDAT
184 60af 'a74031fc RFLG2   JBIT0   SPIF,RFLG2 ;WAIT FOR DATA
185 60b3 a21637    MOV SPIBUF,R22
186 60b6 ff      NOP ;GIVE TIME FOR
187 60b7 ff      NOP ;CONVERSION TO
188 60b8 ff      NOP ;COMPLETE
189 60b9 'da14e8   DJNZ    R20,RLOOP2
190                      ;DISPLAY VALUE
191 60bc 42151a    MOV R21,R26
192 60bf d71a      SWAP R26
193 60c1 730f1a    AND #0FH,R26 ;SAVE MSDIGIT IN R26
194 60c4 42151b    MOV R21,R27 ;SAVE MIDDLE DIGIT IN R27
195 60c7 730f1b    AND #0FH,R27
196 60ca 42161c    MOV R22,R28
197 60cd d71c      SWAP R28
198 60cf 730f1c    AND #0FH,R28 ;SAVE LSDIGIT IN R28
199 60d2 '8e614d   CALL   DISPLAY
200 60d5 a4082e    SBIT1 CSBIT ;DISABLE ADC
201                      ;SEE IF FAST MODE STILL SELECTED
202 60d8 8022    MOV ADATA,A ;WAIT FOR CHANGE
203 60da b7      SWAP A
204 60db 230f    AND #0FH,A
205 60dd * 4d001d   CMP A,R29
206 60e0 '02b4      JEQ RLOOP1
207 60e2 '89ff7b   JMP READ1
208 60e5 f9      RTS

209                      ;
210                      ;SETUP CHANNEL # IN R25
211                      ;
212 60e6 421d19    READ4   MOV R29,R25
213 60e9 720218    MOV #02,R24 ;SET DELAY TO .5SEC
214 60ec f9      RTS

215                      ;
216 .................................
217 .................................
218                      ;
219                      ;ADC
220                      ;
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221                    ;       THIS ROUTINE DIGITIZES THE INPUT ON
222                    ;       THE CHANNEL SPECIFIED IN R25. THE RESULTS
223                    ;       ARE PLACED IN REGISTERS R26, R27, AND R28.
224                    ;
225 60ed   1219        ADC     MOV     R25,A
226 60ef   b7                  SWAP    A
227 60f0   23f0        AND     #0F0H,A       ;CHANNEL # IN MS NIBBLE
228 60f2   240c        OR      #0CH,A        ;16 BITS, MSB 1ST, BINARY
229 60f4   3f72e        SBIT0   CSBIT         ;ENABLE ADC
230 60f7   f70631        MOV     #06H,SPICTL
231 60fa   2139        MOV     A,SPIDAT
232 6100   a74031fc    ADCFLG1 JBIT0   SPIF,ADCFLG1  ;WAIT FOR DATA
233 6103   2139        MOV     A,SPIDAT
234 6105   a74031fc    ADCFLG2 JBIT0   SPIF,ADCFLG2  ;WAIT FOR DATA
235 6109   321637        MOV     SPIBUF,R21    ;SAVE MSBYTE
236 610c   42151a        MOV     R21,R26
237                    ; SAVE DATA
238                    ;
239 611a   42151b        MOV     R21,R27
240 611d   730f1c        AND     #0FH,R26      ;SAVE MSDIGIT IN R26
241 611e   42151c        MOV     R22,R28
242 611f   730f1d        AND     #0FH,R27      ;SAVE MIDDLE DIGIT IN R27
243 6120   42151d        MOV     R23,R29
244 6121   730f1e        AND     #0FH,R28      ;SAVE LSDIGIT IN R28
245 6122   3a74031fc    ADCFLG1 JBIT0   SPIF,ADCFLG1  ;WAIT FOR DATA
246 6125   f9                  RTS
247                    ;
248 6126   7d0118      DELAY   CMP     #1,R24        ;SEE IF NO DELAY
249 6129  '0601                JNE     DELAY1
250                    ;
251                    ; THIS ROUTINE USES TIMER 1 AS
252                    ; A GENERAL PURPOSE TIMER TO
253                    ; DELAY 0, .5, OR 2 SECONDS.
254                    ; R24 IS SET AS FOLLOWS:
255                    ; 1 = 0 SEC.
256                    ; 2 = 0.5 SEC.
257                    ; 3 = 2 SEC.
258                    ;
259 612b   7d0218      DELAY1  CMP     #2,R24        ;SEE IF 0.5 SEC DELAY
260 612d   7d0318      DELAY2  CMP     #3,R24        ;SEE IF 2 SEC DELAY
261                    ;
262 6130   7f1642        MOV     #16H,T1C11     ;0.5 SEC COMPARE VALUE
263 6133   f7e343        MOV     #0E3H,T1C12
264 6136   a40749         DLOOP OR      #07H,T1CTL1  ;SET PRESCALER TO 256
265 6139   a4014a          OR     #1,T1CTL2      ;START COUNTER AT ZERO
266 613c   a3df4b        SBIT0   TOUT     ;CLR CMP FLAG
267 613f   a7204bfc    DFLAG1 JBIT0   TOUT,DFLAG1  ;WAIT FOR TIMEOUT
268 6142   f9                  RTS
269 6145   f75b42      DELAY2  MOV     #5BH,T1C11     ;2-SEC COMPARE VALUE

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276 6148  f78d43        MOV     #8DH,TC12
277 614b  '00ea          JMP     DLOOP
278
279
280
281
282
283
284
285
286
287
288 614d  321a  DISPLAY  MOV     R26,B          ;OUTPUT LSD
289 614f  'aa6175      MOV     *DTBL[B],A
290 6152  2122        MOV     A,ADATA
291 6154  a3df2e       SBIT0   DOUT1          ;STROBE IT
292 6157  a4202e       SBIT1   DOUT1
293 615a  321b          MOV     R27,B          ;OUTPUT MIDDLE DIGIT
294 615c  'aa6175      MOV     *DTBL[B],A
295 615f  2122        MOV     A,ADATA
296 6161  a3bf2e       SBIT0   DOUT2
297 6164  a4402e       SBIT1   DOUT2
298 6167  321c          MOV     R28,B          ;OUTPUT MSD
299 6169  'aa6175      MOV     *DTBL[B],A
300 616c  2122        MOV     A,ADATA
301 616e  a37f2e       SBIT0   DOUT3
302 6171  a4802e       SBIT1   DOUT3
303 6174  f9           RTS
304 6175  00          DTBL    .BYTE   00H            ;0
305 6176  08          .BYTE   08H            ;1
306 6177  04          .BYTE   04H            ;2
307 6178  0c          .BYTE   0CH            ;3
308 6179  02          .BYTE   02H            ;4
309 617a  0a          .BYTE   0AH            ;5
310 617b  06          .BYTE   06H            ;6
311 617c  0e          .BYTE   0EH            ;7
312 617d  01          .BYTE   01H            ;8
313 617e  09          .BYTE   09H            ;9
314 617f  05          .BYTE   05H            ;A
315 6180  0d          .BYTE   0DH            ;B
316 6181  03          .BYTE   03H            ;C
317 6182  0b          .BYTE   0BH            ;D
318 6183  07          .BYTE   07H            ;E
319 6184  0f          .BYTE   0FH            ;F
320
321
322 7ffe                    .SECT   "RESET",7FFEH  ;RESET VECTOR ADDR
323 7ffe  6000        .WORD   6000H          ;PROGRAM START
324
325 .END

No Errors,  No Warnings
5.2 Flow Charts

The flow charts for the TLC2543 EVM are shown in Figure 5–1 through Figure 5–6.

Figure 5–1. Main Program Flow Chart

The flowchart is shown with the following steps:

1. **Set up Stack Pointer**
2. **Call INIT** (Initialization Subroutine, see Figure 5–2)
3. **Call READSW** (Read Input Switch Selection, see Figure 5–3)
4. **Call ADC** (Convert Analog Input to Digital, see Figure 5–4)
5. **Call DISPLAY** (Display Results, see Figure 5–5)
6. **DELAY** (Delay, see Figure 5–6)
Figure 5–2. Initialization Subroutine Flow Chart

Initialization Subroutine

START

Set up Ports, SPI, and Registers

Flash Display 3 Times

RETURN
Figure 5–3. Read Input Switch Subroutine Flow Chart

Read Input Switch Selection Subroutine

START

Read DIP Switch Setting

Same as Before?

Yes → Return

Delay 2 Seconds

No → Power-Down Mode Selected?

Yes → Blank Display and Power-Down ADC

No → Power-Down Mode Still Selected?

Yes → 1

No → Any More Changes?

Yes → 1

No → No → 2

1

2
Figure 3–3. Read Input Switch Subroutine Flow Chart (Continued)

Read Input Switch Selection Subroutine (continued)

2

Fast Mode Selected?

Yes

Select Channel 4 and Digitize 20 Times

Display Data

Yes

Fast Mode Still Selected?

No

Save Channel Number

Return

1
Figure 5–4. Analog-to-Digital Convert Subroutine Flow Chart

Convert Analog Input to Digital Subroutine

START

Get Channel Number, 16-Bit Data, and MSB First for ADC

Enable ADC

Start Serial Output (SPI)

Data Back From ADC?

Yes

Save Data

Start Clock Again for Last 8 Bits

No

Data Back From ADC

Save Data in R26, R27, R28
Disable ADC

Return
Figure 5–5. Display Subroutine Flow Chart

Display Results Subroutine

START

Get Bit Pattern for LSD

Output Data and Strobe It

Get Bit Pattern for Middle Digit

Output Data And Strobe It

Get Bit Pattern for MSD

Output Data And Strobe It

Return
Figure 5–6. Delay Subroutine Flow Chart

Flow Subroutine
START

No Delay Selected?
Yes
Return

No

0.5 Second Delay Selected
Yes
Set up Timer 1 Control Register For 0.5 Second

No

Set up Timer 1 Control Register For 2 Seconds

No

Timer Timed Out?
Yes
Return