

## **TCA7408EVM, TCA5405EVM**

This user's guide describes the characteristics, setup and use of the TCA7408EVM/TCA5405EVM Evaluation Module (EVM). This user's guide includes set-up instructions, a schematic diagram, a bill of materials, printed-circuit board layout drawings, software instructions, and operation instructions.

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## 1 Introduction

The TCA7408-5405EVM is designed to show the used of multiple TI products on a single evaluation board. It shows how the single-wire 5-bit output expander TCA5405 is used to generate LED blinking functions. The Single wire interface is implemented using a single GPIO port on the MSP430, and very simple firmware embedded in the device. The TCA7408 GPIO expander is used to an input handler, that detects Key presses and notifies the MSP430. The EVM also has the TPL0401 that is used for RGB color mixing in conjunction with the TLC59108.

## 1.1 Features

- Works with MSP430 Launchpad
- Illustrates the use of TPL0401DPOT for color mixing
- TCA7408 used for Key press detection
- Shows the use of Single wire self timed interface in TCA5405
- Color mixing and LED blinking control

## 1.2 TPL0401A/B

The TPL0401 is an I<sup>2</sup>C bus controlled, single channel, linear-taper digital potentiometer with 128 wiper positions. TPL0401A/B have an end-to-end resistance of 10k ohms and the low terminal internally connected to ground.

## 1.3 TCA5405

The TCA5405 is a 5-bit output expander controlled using a single wire input. This device is ideal for portable applications as it has a wide VCC range of 1.65V to 3.6 V. The TCA5405 uses a self-timed serial data protocol with a single data input driven by a master device synchronized to an internal clock of that device.

## 1.4 TCA7408

This 8-bit I/O expander for the two-line bidirectional bus (I<sup>2</sup>C) is designed to provide general-purpose remote I/O expansion via the I<sup>2</sup>C interface [serial clock (SCL) and serial data (SDA)]. The major benefit of this device is its wide VCC range. It can operate from 1.65-V to 3.6-V on the GPIO-port side and 1.65-V to 5.5-V on the SDA/SCL side. This allows the TCA7408 to interface with next-generation microprocessors and microcontrollers on the SDA/SCL side, where supply levels are dropping down to conserve power. The TCA7408 open-drain interrupt (INT) output is activated when any GPIO set as an input has a transition to the state opposite of that in the Input Default State register and the corresponding bit in the Interrupt Mask Register is set to 0. It is used to indicate to the system master that an input has changed to a pre-determined state.

## 1.5 TLC59108

The TLC59108 is an I<sup>2</sup>C bus controlled 8-bit LED driver that is optimized for red/green/blue/amber (RGBA) color mixing and backlight application for amusement products. Each LED output has its own 8-bit resolution (256 steps) fixed-frequency individual PWM controller that operates at 97 kHz, with a duty cycle that is adjustable from 0% to 99.6%. The individual PWM controller allows each LED to be set to a specific brightness value. An additional 8-bit resolution group PWM controller has both a fixed frequency of 190 Hz and an adjustable frequency between 24 Hz to once every 10.73 seconds, with a duty cycle that is adjustable from 0% to 99.6%. The group PWM controller dims or blinks all LEDs with the same value. TLC59108 scales up the reference current set by the external resistor (R<sub>ext</sub>) to sink the output current (I<sub>out</sub>) at each output port.

## 1.6 Requirements

In order to operate this EVM, the following components must be connected and properly configured.

### 1.6.1 LaunchPad

A Texas Instruments LaunchPad (MSP-EXP430G2) with the male headers and an MSP430G2553 microcontroller installed is required to run the board. A LaunchPad can be acquired here (<https://estore.ti.com/MSP-EXP430G2-MSP430-LaunchPad-Value-Line-Development-kit-P2031.aspx>)

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**NOTE: IMPORTANT:** The code to control the TCA7408EVM/TCA5405EVM was written from an MSP430G2553 and will not work with the MSP430 chips that are included with the LaunchPad kit.

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## 1.6.2 Power Supply (\*Optional)

To ensure correct functionality of the LEDs a 5V supply at 300mA is recommended (refer to note in section 2.3.1). If not using a USB cable to power the LaunchPad a 3.3V power supply at 200mA is required.

## 2 Setup

This section describes the jumpers and connectors on the EVM.

### 2.1 Connectors and Jumpers

#### 2.1.1 J1 & J2 – LaunchPad Headers

These connectors mate with the male headers on the LaunchPad.

#### 2.1.2 J3 – External LED Power

This connector is where the external +5V supply is attached to power the two RGB LEDs.

#### 2.1.3 J4 – TCA7408 GPIO

This is a pin out of the four unused GPIO pins from the TCA7408, GPIO4-GPIO7.

#### 2.1.4 J5 – Feedback loop

For the TPL0401A to function as a voltage reference circuit the negative feedback loop must be shorted, placing a jumper across this header will short the inverting input to the output.

#### 2.1.5 J6 – LED or Op-amp

This header controls what the TPL0401B is attached to. When shorted across position 1 and 2 the TPL0401B is connected in series with the external resistor to control the current through the LED driver. When shorted across position 2 and 3 the TPL0401B is connected to the inverting input of the op-amp to change the gain of the circuit.

#### 2.1.6 J7 – Op-amp input

This header controls the input to the non-inverting pin of the LMV321. When shorted across position 1 and 2, the TPL0401A in a voltage divider mode is attached to the non-inverting input of the LVM321. This setup is used to test the voltage reference setup. When shorted across pins 2 and 3, the SMA connector is attached to the non-inverting input.

#### 2.1.7 J9 – Test Points

This connector offers test points for the serial data lines, SDA, SCL and the DIN that drives the TCA5405.

**Table 1. Description of Connectors and Jumpers**

Label	Description
J1, J2	Connectors to interface with LaunchPad
J3	External 5V for LED
J4	GPIO4-GPIO7 from TCA7408
J5	Control jumper to short feedback loop
J6	Jumper to control LED or Op-Amp
J7	Jumper to control input to Op-Amp
J8	SMA/B Footprint for external input
J9	Test points for DIN, SDA and SCL

## 2.2 Hardware Setup

There are three different modes that the EVM can be used in, LED mode, Voltage reference mode, and Variable gain mode. To setup any of these three modes, begin by connecting the EVM to the LaunchPad. Note the location of the VCC and GND pins on headers J1 and J2 on both the LaunchPad and the EVM to ensure correct installation.

Install a shorting jumper across pins 1 and 2 of J6. Connect an external +5V supply to J3 and either connect the LaunchPad to a computer through USB or connect a 3.3V power supply to J6\* on the LaunchPad to power it up.

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**NOTE:** : It can be possible to power up the LEDs by connecting a wire from the VCC pin of J6 on the LaunchPad to the positive pin of J3. A 5V supply might be required because the max voltage drop across the blue LED plus the drop across the TLC59108 is larger than the supply voltage of the LaunchPad.

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## 3 Operation

The TCA5405 will control when D1-D5 light up. TPL0401B is connected in series to the REXT of the TLC59108 LED driver this setup will control D6 and D7. Each color is set to a fixed PWM to ensure baseline brightness is similar. Color mixing is then accomplished through unique methods. The desired current is set by changing the W-L resistance of the TPL0401B and the desired LED is switched on. This repeats for the other colors and then starts over. The LEDs are multiplexed at about 1000 Hz.

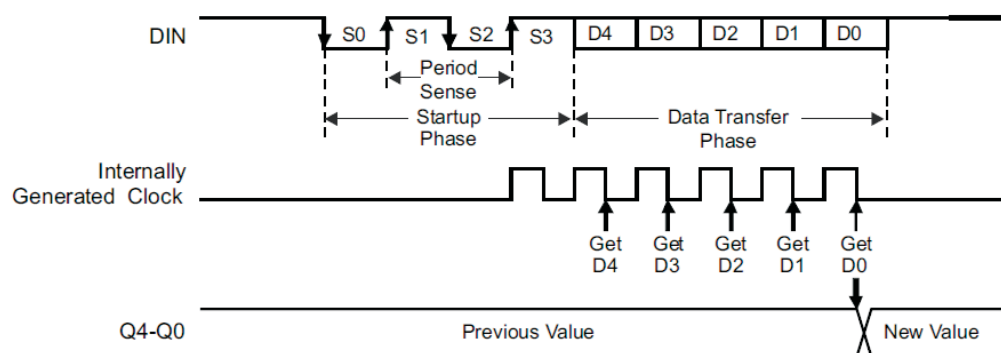
After setting up the EVM as described in section 2.3.1, LEDs D1-D5 should be blinking and D6 and D7 will be blue. To increase the speed at which D1-D5 blink press SW1 and to decrease the speed press SW2.

There are 25 different colors that can be created with D6-7 starting with blue and ending with green. To step through the colors from blue to green press S4. To step through the colors from green to blue press S3.

## 4 MSP430 Code

### 4.1 TCA5405

Within the source code for the MSP430 there are two different methods to handle sending data to the TCA5405. This section will explain how the TCA5405 functions and how the MSP430G2xx3 code works.



**Figure 1. Data Flow for TCA5405**

### 4.1.1 TC5405 Overview

As shown in [Figure 1](#), a ten bit serial transfer is required to set the five outputs on the TCA5405. The first four bits, 0101 (S0-S3), act as a start flag for the TCA5405. S0 is a start bit and S1-S3 are the clock sense bits for the TCA5405. The next five bits (D4-D0) are the data bits associated with each of the outputs. The tenth bit returns the serial line back to high to ready the TCA5405 for the next input.

In the source code there are two methods to handle this communication. These functions are located in `Single_Wire.c`

1. Use a GPIO (general purpose input/output) and a clock delay to emulate S0-D0.
2. Use one of the MSP430 timers to change the output at a specified bit interval.

### 4.1.2 `bit_bang_TCA5405_byte(unsigned char byte)`

The function `bi_bang_TCA5405_byte(unsigned char byte)` will emulate the required ten bits for communication with the TCA5405. This function works very simply by driving a GPIO pin to high or low and utilizing the `_delay_cycles()` function to hold the value. After each assert on the GPIO pin a `_delay_cycles(16)` is called to wait roughly 2 microseconds before the next bit. The section that handles the data bits (D4-D0) only uses a `_delay_cycles(10)` function; this is to adjust for the time spent on if statements.

### 4.1.3 `send_TCA5405_byte`

The function `send_TCA5405_byte(unsigned char byte)` along with `5405_Timer_ISR()` implements the required serial data by using one of the MSP430 timers. When a byte is sent to `send_TCA5405_byte()`, the function adds the start flag (S0-S3) to the beginning and the stop bit (1) to the end (LSB), stores the new value to a global variable, and enables the timer interrupts. After a set number of clock cycles defined by `NEXT_BIT_TIME`, `5405_Timer_ISR()` is called and adjusts the output of the P2.0 accordingly.

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**NOTE:** The start flag S0-S3 is hard coded into each of these methods

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## 5 Schematics, Layout, and Bill of Materials

### 5.1 Schematics

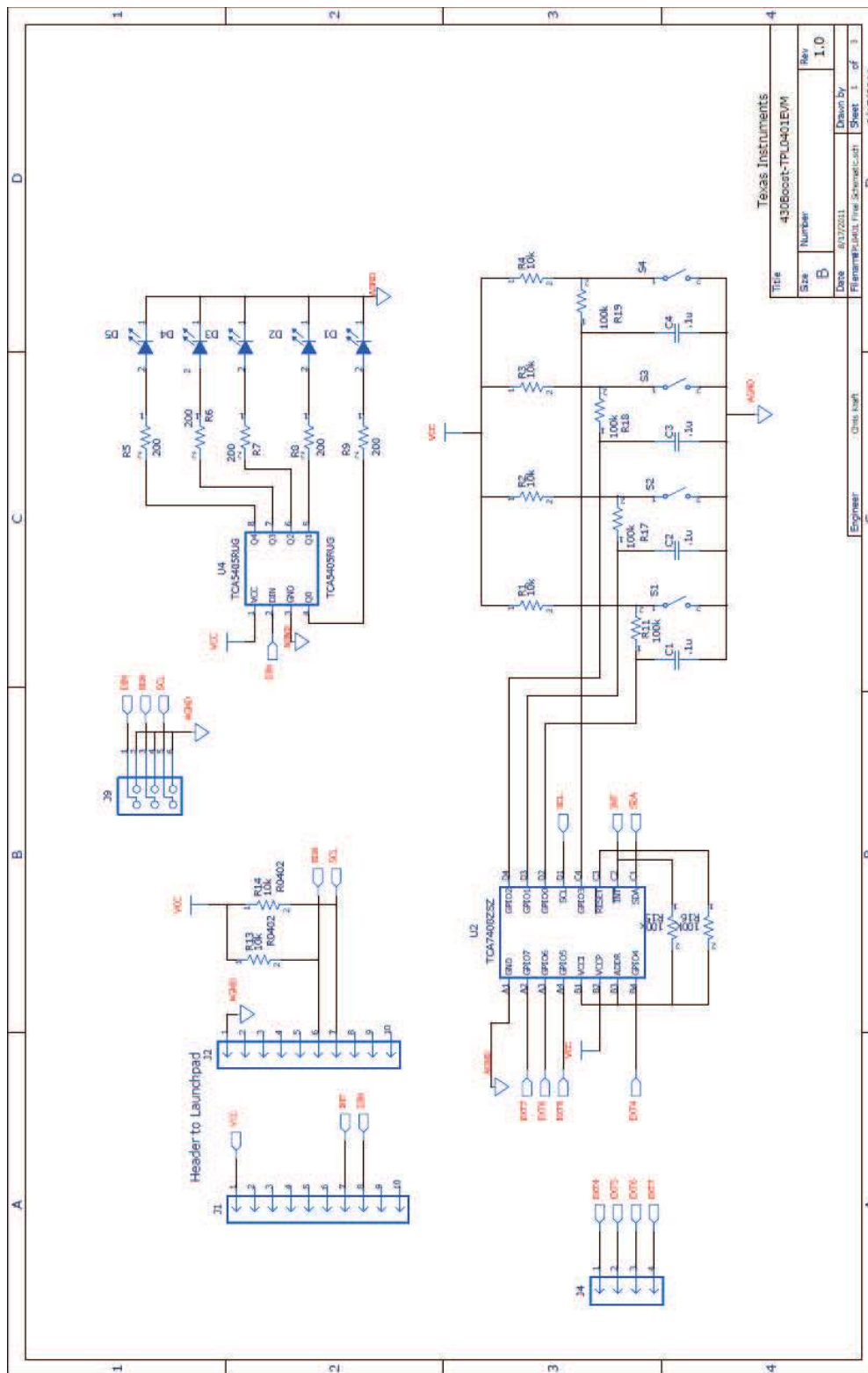


Figure 2. TCA5405, TCA7408 Schematic

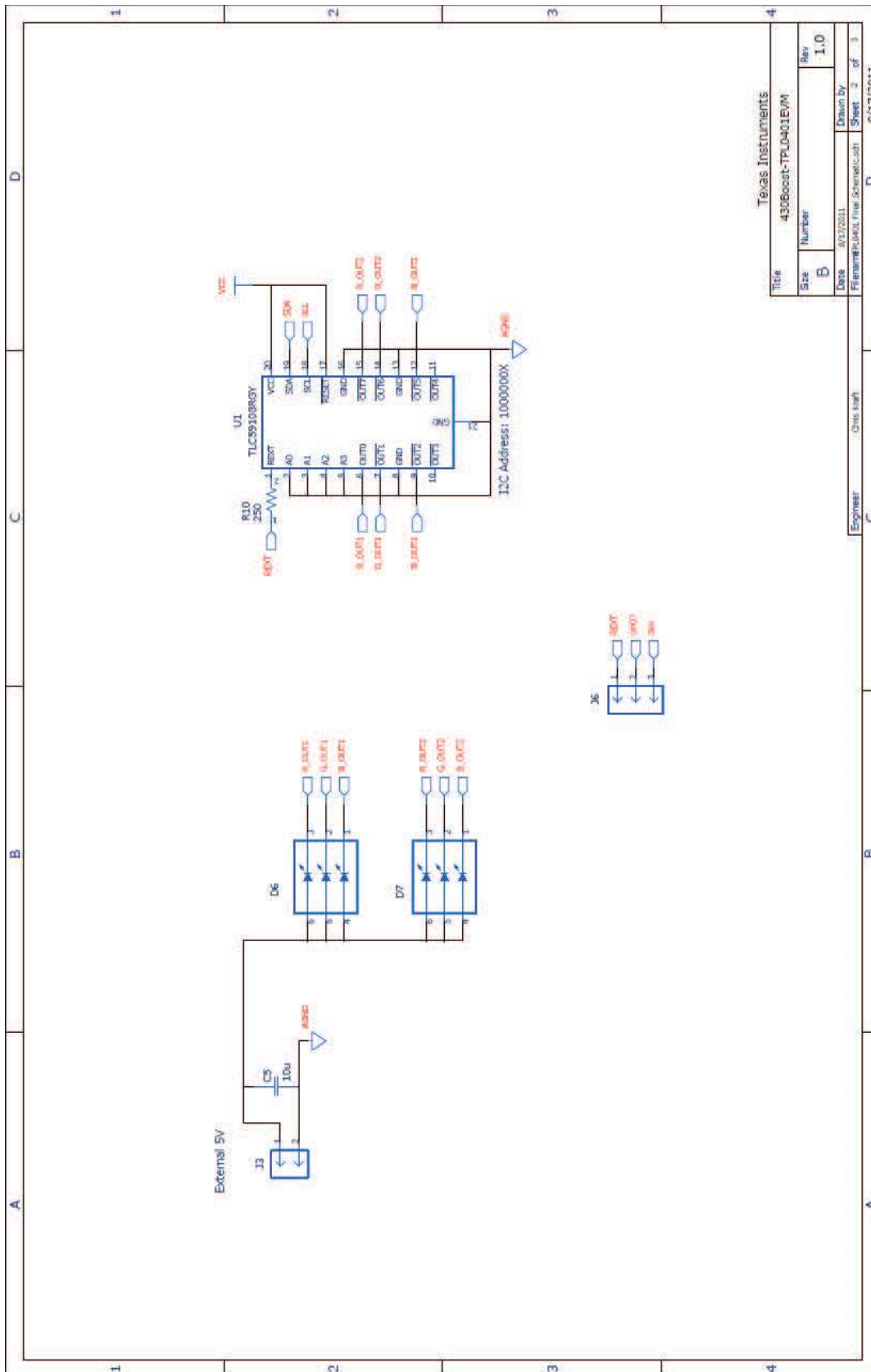


Figure 3. TLC59108 Schematic

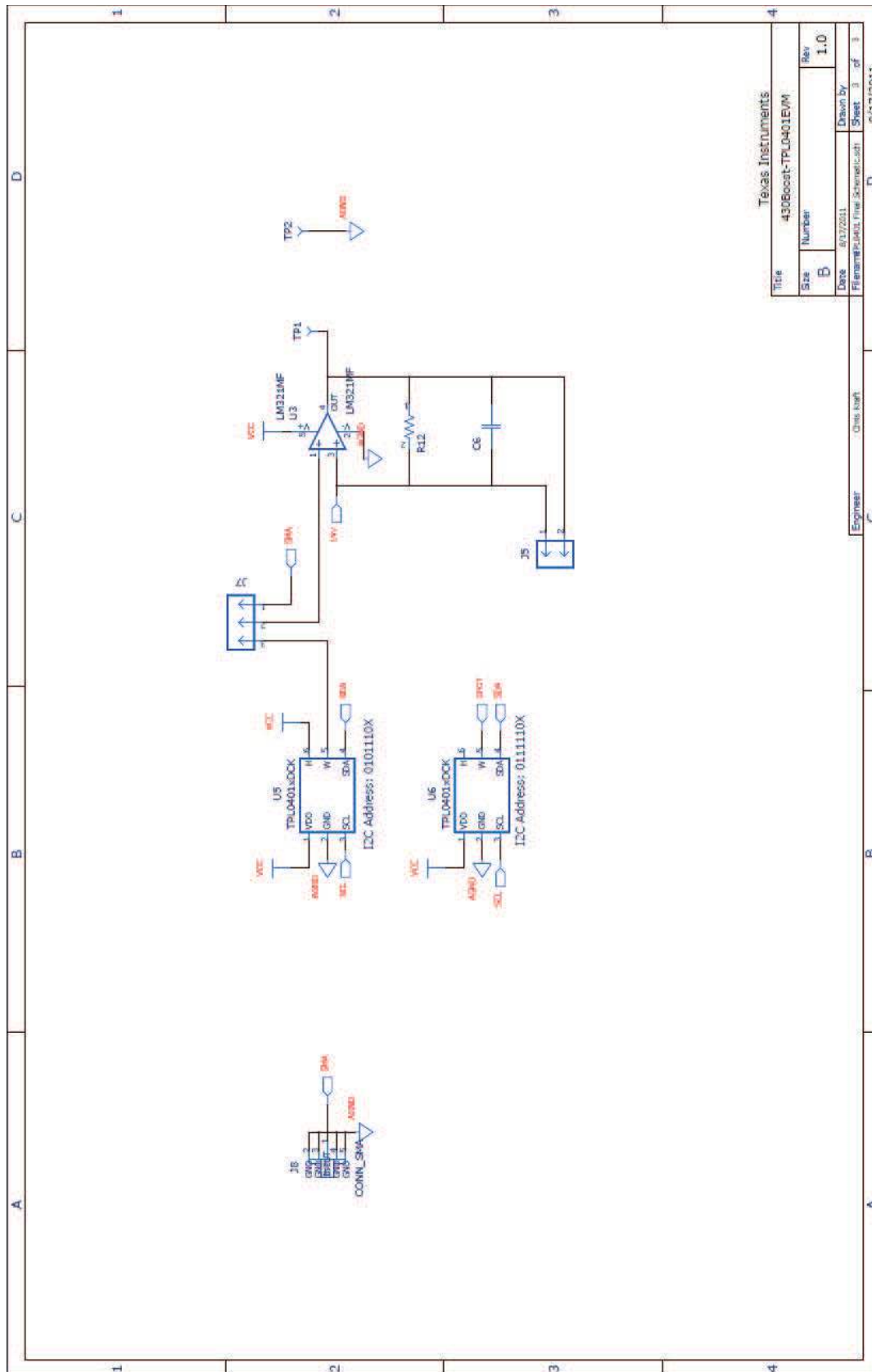


Figure 4. TPL0401 Schematic



5.2 Layout

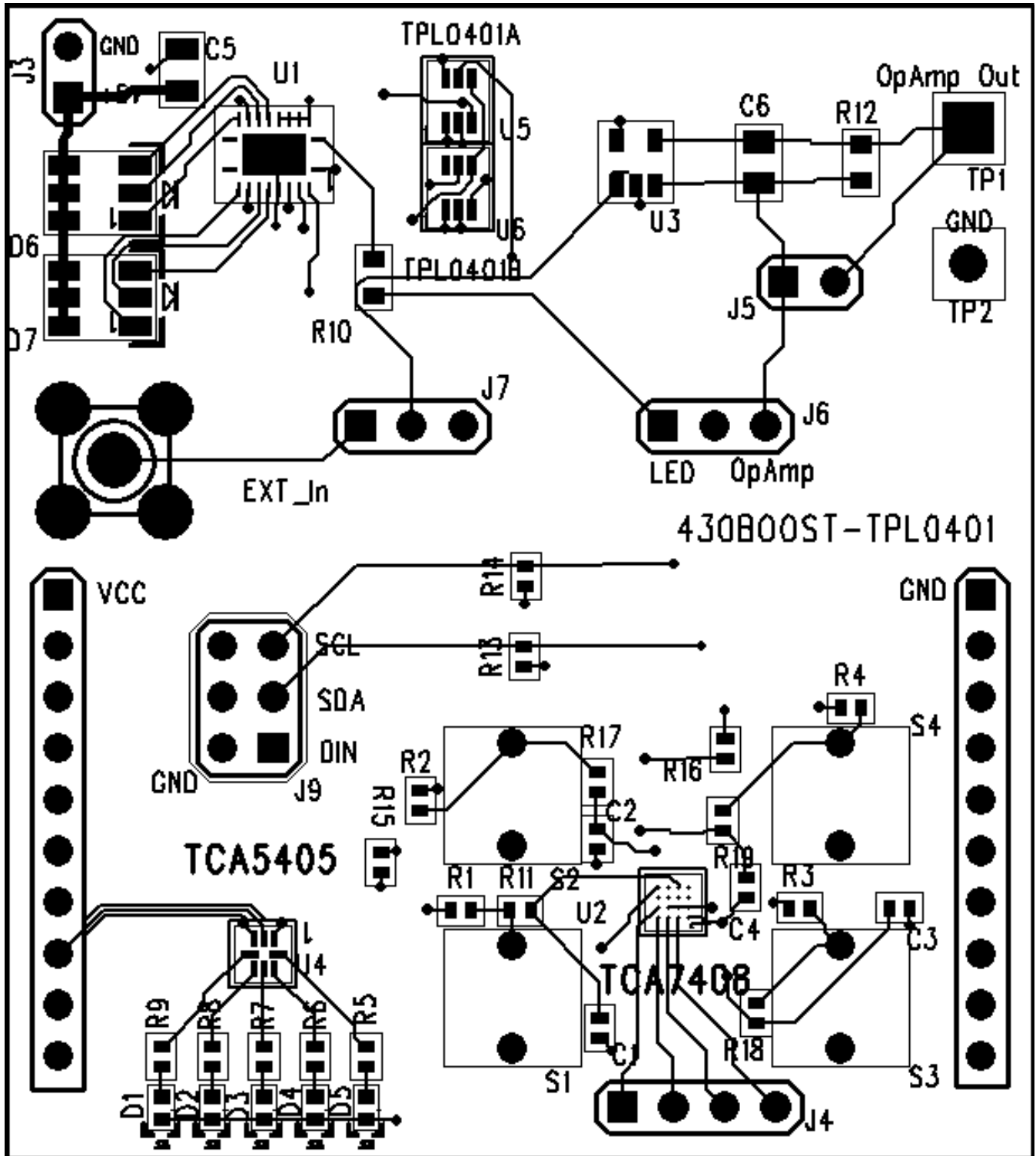


Figure 5. Routing, Assembly and Silkscreen Top

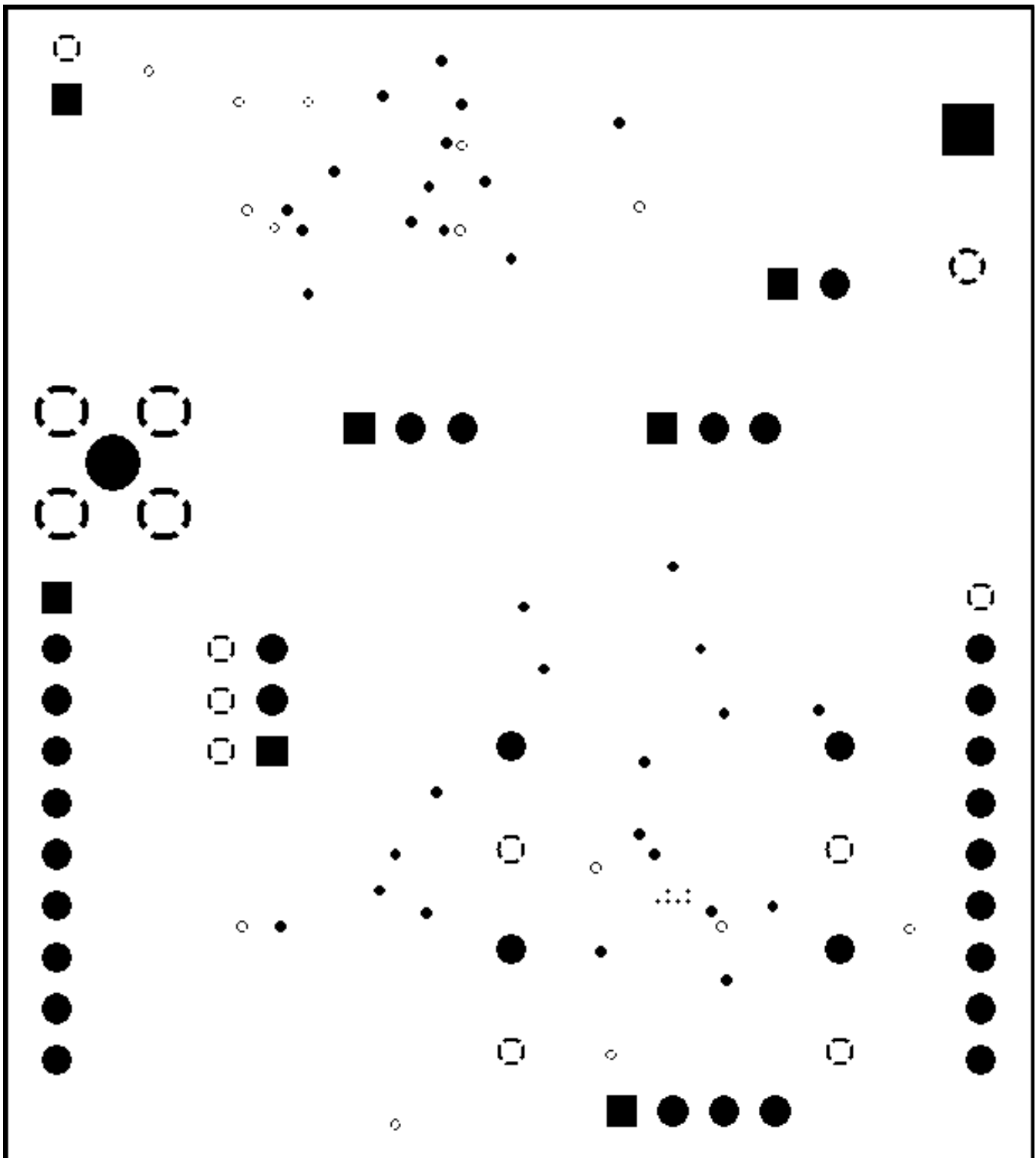


Figure 6. Layer 2 Power Plane

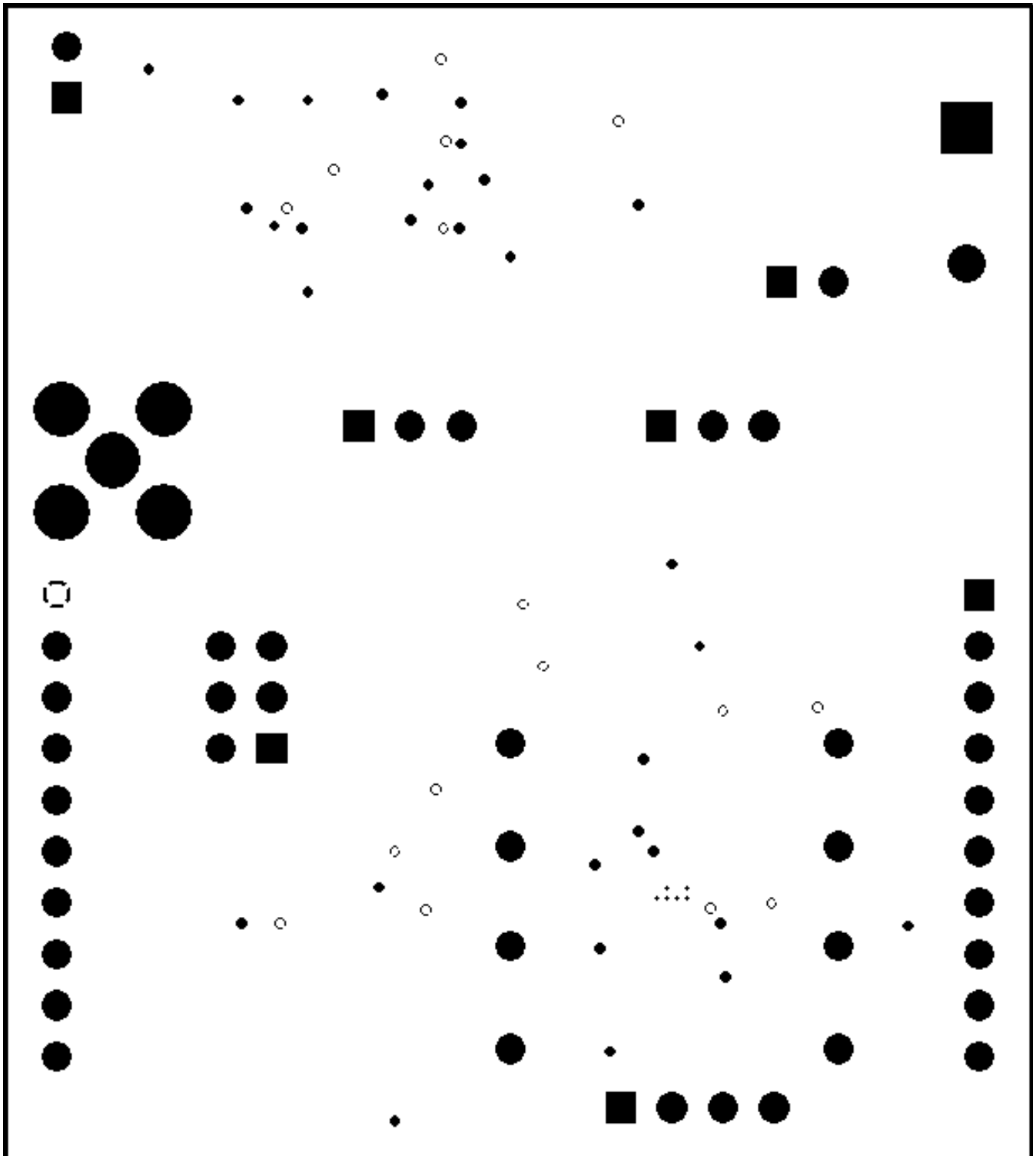


Figure 7. Layer 3 Ground Plane

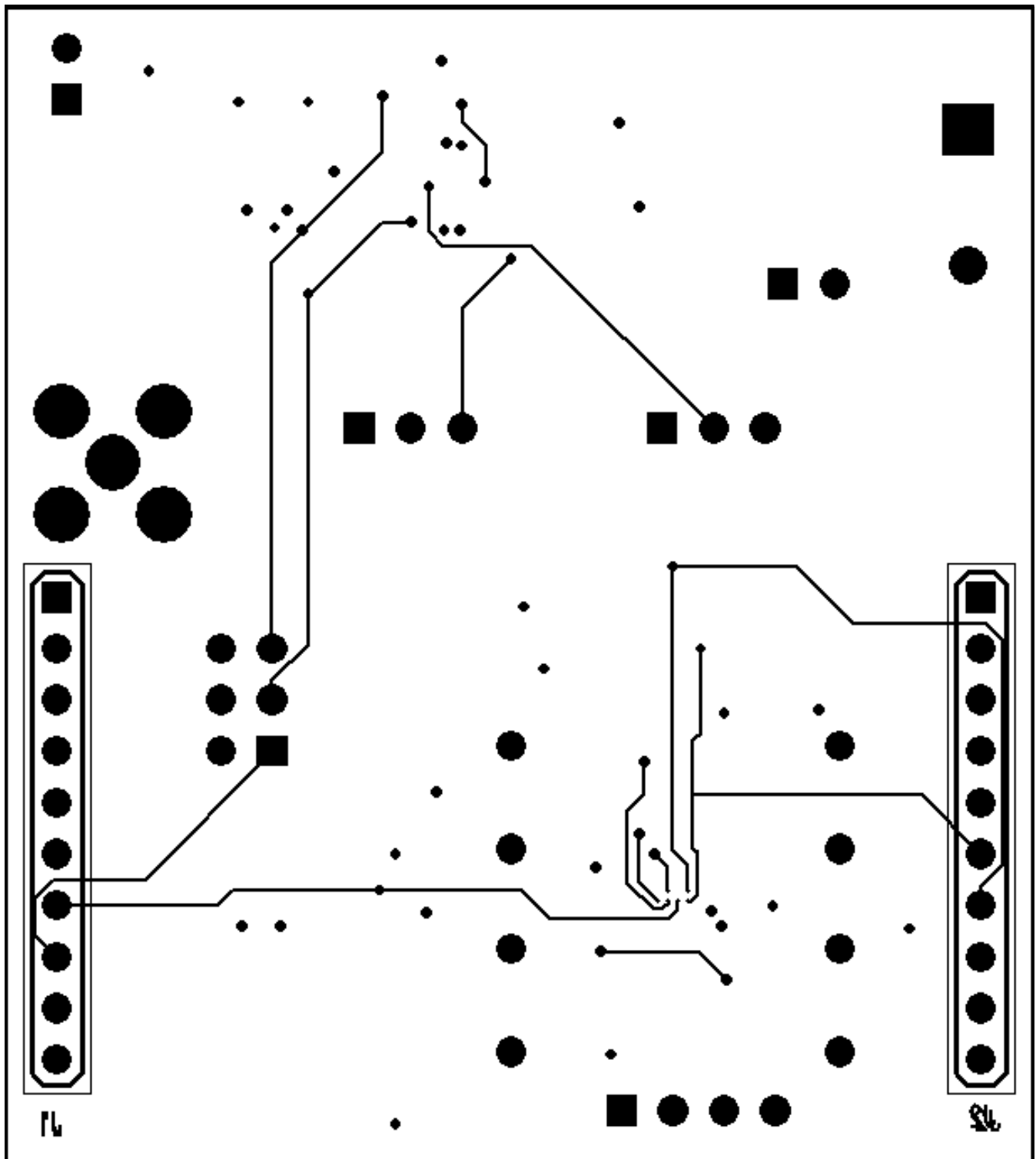


Figure 8. Routing and Assembly Bottom

### 5.3 Bill of Materials

**Table 2. TCA7408EVM/TCA5405EVM Bill of Material**

Qty	RefDes	Value	Description	Part Number	MFG	Notes
4	C1-4	0.1 $\mu$	Capacitor, Ceramic			
1	C5	10 $\mu$	Capacitor, Ceramic			
1	C6		Capacitor, Ceramic			DNI
1	J8		Connector, SMA , Straight, PC mount	901-144-8RFX	AMP	DNI
5	D1-5	SML-P12PTT86	Diode, LED, GREEN 2.2V 20mA	SML-P12PTT86	ROHM	
2	D6-7	APF3236SURKZGQ BDC	LED SMD TRI Color	APF3236SURKZGQBDC	Kingbright	
2	J3 J5		Header, Male 2-pin, 100mil spacing		Sullins	
2	J6-7		Header, Male 3-pin, 100mil spacing		Sullins	
1	J4		Header, Male 4-pin, 100mil spacing		Sullins	
2	J1-2	PPTC101LFBN-RC	Header, Female 10-pin, 100mil spacing	PPTC101LFBN-RC	Sullins	
1	J9		Header, Male 2x3-pin, 100mil spacing		Sullins	DNI
2	R15-16	100k	Resistor, Chip, 1/16W 5%			
10	R1-R4 R11 R13-R14 R17-R19	10k	Resistor, Chip, 1/16W 5%			
5	R5-9	200	Resistor, Chip, 1/16W 1%			
1	R10	250	Resistor, Chip, 1/16W, 1%			
1	R12	{value}	Resistor, Chip, 1/16W, 5%			DNI
1	TP2	5001	Test Point, Black, Thru Hole Color Keyed	5001	Keystone	
1	TP1	5013	Test Point, Orange, Thru Hole	5013	Keystone	
4	S1-4	EVQ221304M	Switch, SPST, 20-mA, 15-V	EVQ21304M; EVQ21305R; EVQ21307K	Panasonic	Prefer EVQ21304M if unavailable use 305R or 307K
1	U3	LMV321IDBVR	IC Low Power Single Op-amp	LMV321IDBVR	TI	
1	U4	TCA5405RUG	IC, Low Voltage 5-Bit Self-Timed, Single-Wire Output Expander	TCA5405RUG	TI	
1	U2	TCA7408ZSZ	IC, Low-Voltage 8-Bit I2C and SMBus I/O Expander	TCA7408ZSZ	TI	
1	U1	TLC59108RGY	IC, 8-BIT Fm+ I2C-Bus Constant-Current LED Sink Driver	TLC59108RGY	TI	
1	U5	TPL0401ADCK	IC, Digital POT, 1Chan, 128Tap	TPL0401ADCK	TI	
1	U6	TPL0401BDCK	IC, Digital POT, 1Chan, 128Tap	TPL0401BDCK	TI	

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### General Statement for EVMs including a radio

*User Power/Frequency Use Obligations:* This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

### For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

#### Caution

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

### FCC Interference Statement for Class A EVM devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

### **FCC Interference Statement for Class B EVM devices**

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

### **For EVMs annotated as IC – INDUSTRY CANADA Compliant**

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

### **Concerning EVMs including radio transmitters**

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

### **Concerning EVMs including detachable antennas**

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

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1. Use this product in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

**Certain Instructions.** It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

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