Application Note

Power Supply Sequencer with Hot Swap

AN023702-1008

Abstract

This Application Note describes Zilog's Z8 Encore! XP® based Power Supply Sequencing and Supervisor of a multi-output power supply with Hot Swap. The application note also describes how the peripherals of Z8 Encore! XP are used for functions like Hot Swap, Sequencing ON/OFF, and Supervising the multiple power supplies in a complex powered system at low cost. The microcontroller is used as a sequencer and can be programmed for various options (under voltage, over voltage, over current, temperature, ON sequence, and OFF sequence).

Note: *The source code files associated with this Application Note,* `AN0237-SC01.zip`*, and* `AN0237-SC02.zip` *are available for download on* www.zilog.com.

Features of Power Supply Sequencer

The features of power supply sequencer include:

1. Sequencing of 1.8 V, 3.3 V, and 5.0 V switching power regulators.
2. Hot Swap output for electrical load drawing high start up current from the main supply.
3. Programmable delay between power regulators that are switched consequently.
4. Programmable ON Ramp and OFF Ramp for 12 V output voltage.
5. Programmable over voltage, under voltage, over current, and over temperature for each of the power regulators.
6. Supervision of output voltage from the power supplies for under voltage and over voltage.
7. Monitoring of the total current drawn by all the four power regulators.
8. Over all system temperature monitoring using on-chip temperature sensor.
9. UART interface for display and keypad controller, for on-board settings and display of parameters (voltage, current, temperature, and sequence).
10. Status display of voltage, temperature, and ON/OFF sequence on LCD display.

Discussion

The power supply sequencer performs the function of sequencing the power for a circuit supplied with various voltage levels and thereby maintaining the proper operation of the circuit. The Hot Swap function is used to change the output voltage level from minimum voltage to the maximum voltage or vice versa. This change in the voltage is accomplished using pulse-width modulation (PWM) function of the timers.The main applications involve circuits with processors controlling various peripherals.

Power Supply Sequencing—Needs and Challenges

In most of the electronic systems, it is important to monitor system voltages to ensure that the processors and other ICs remain reset during power up, and to detect the occurrence of brownout conditions (low voltage conditions). This monitoring minimizes code execution problems, which corrupt memory or cause systems to execute improperly. In high-end systems, it is also critical to ensure proper sequencing of many power supplies within these systems. Proper sequencing prevents latch-up conditions, which create system problems or damage important components such as microcontrollers (µCs), DSPs, ASICs, or Microprocessors (µPs). Generally, one or more supervisory products are required to implement the proper sequencing and monitoring functions. Conventionally, many of these functions have been performed with power-on resets. But as the number of supply voltages are increased, the number of devices required to perform this duty also grew, thus compounding complexity, cost, and the board space consumed.

Monitoring and Sequencing Complex Systems

The easiest way to monitor a supply voltage is with either a Power-On Reset (POR) or a voltage detector circuit. These devices can monitor a single voltage or multiple voltages. After the monitored supply voltage has powered up and exceeded the PORs threshold voltage, the PORs output does not de-assert until it reaches a specified time period. This allows both (processor and peripheral) the system clocks to stabilize, and the system boot routine to initialize before permitting the microcontroller to operate. These PORs and voltage detectors can also be used to sequence power supplies. Connecting the output of a POR that is monitoring one regulator to the shutdown pin of the next regulator is called **Daisy-Chaining**. One regulator will then turn ON/OFF after the other, once the PORs time delay has elapsed. As the number of system supply voltage increases, voltage monitors, and supervisors that monitor multiple voltages become necessary. However, as it is common for ten to fifteen voltages to power a complex system, several such devices are often needed.

Challenges when Using Multiple Supervisors

Using the multiple supervisor approach has its own problems. One of them is finding devices with the correct thresholds. Although, there are number of standard voltages, such as 3.3 V, 2.5 V, 1.8 V, 1.5 V, and 1.2 V, many non-standard voltages have to be monitored. This requires external resistor-dividers to set the monitored thresholds. If the system supply voltages change (for example, if you lower an ASIC's core voltage to reduce power consumption, or increase it to enhance the ASIC's performance), you may have to change the resistor values to accommodate these new voltages. Obtaining this flexibility requires these additional external resistors, and thus more board space and cost. The same problems occur while selecting the correct reset time-out periods. Another problem with multiple supervisors occurs when a system provides a specific power-up sequence. When larger numbers of supply voltages power a system, the **Daisy-Chaining** technique mentioned above may not be capable of handling the timing for various supplies coming up. Also, as the sequencing requirements change during development, altering circuitry to accommodate those later changes becomes problematic. An additional sequencing problem can occur when these large systems use silver box or brick power supplies.

These supplies simplify power supply design, but creates a problem when a particular power-up sequence is required. For example, a brick supply that provides multiple output voltages might only have a single enable pin. Therefore, all its supply voltages turn ON and OFF at the same time under the control of that one pin. A brick supply with multiple enable (or shutdown) inputs can resolve this problem. However, if multiple ICs share the same supplies (for example, a 3.3 V input/output logic supply and a 1.8 V core supply), the requirements of the two ICs may conflict. One device might require its core supply to come up before its input/output supply, while the second device might require its supplies to sequence in the opposite order. This can be resolved with an external switch, such as a MOSFET. For low-power applications, you can use a p-channel MOSFET, which is generally more expensive than an n-channel MOSFET, but simpler to use. An n-channel MOSFET is optimal for higher current applications, because its lower on-resistance reduces the voltage drop across the switch. An n-channel can be used for very low voltage cores as well. However, to enhance an n-channel MOSFET, a high supply voltage must be available to provide a suitable gate-to-source voltage.

Developing the Power Supply Sequencer with Hot Swap using Z8 Encore! XP® MCU

This section provides an overview of the functional architecture of the power supply sequencer implementation using the Z8 Encore! XP MCU.

Hardware Architecture

Figure 1 on page 4 displays the hardware block diagram of the sequencer application. The Z8 Encore! XP based sequencer features the following hardware blocks:

- Sequencer
- User Interface Controller

Sequencer

The Z8 Encore! XP 4K controller is the core of the sequencer block. The Timer0 pin of the controller is connected to the Gate of the power MOSFET and port C, bit 4 to bit 7 pins are used as GPIO and connected to ON/OFF pins of power regulators. The output of the 1.8 V, 3.3 V, and 5.0 V switching power regulators are connected to the ADC input pins of the controller. Two switches **START** and **STOP** are connected to two pins (PA3 and PA4) of the sequencer controller, which are active **Low**. When the **START** key is momentarily pressed, the sequencer by use of the Timer0 gradually increases the width of the PWM applied to the MOSFET Gate till the output power at connector J9 reaches a voltage equal to the input voltage. The sequencer controller then switches on the power regulators by changing the state of the voltage on the ON/OFF pin from 0 to 3.3 V. When the sequencer controller is powered, it continuously monitors the output of each switching regulator using the ADC. The monitored data is transmitted over the serial link connected between the sequencer controller and the user interface controller.

The data is transferred from the sequencer to the user interface controller after every five set of ADC readings are obtained and averaged. The user interface controller has to be interrupt driven on serial communication to accept the data from the sequencer controller. After the sequencer controller is turned ON, if the output voltage of the switching regulators, current, or the temperature exceeds the set limits the sequencer switches OFF all the regulators in a sequence set by the user. The sequencer controller then gradually decreases the pulse width connected to the power MOSFET till the output voltage at the connector J9 reaches zero.

The power supply for the controllers is obtained from external power source of 12 V regulated to 5 V and applied to the LCD display and keyboard section. The 5 V is further reduced to 3.3 V using a linear regulator for processor operation. 12 V is the input voltage for the switching regulators which further converts the voltages to various levels (1.8 V, 3.3 V, and 5 V) required for different kinds of load.

User Interface Controller

The user interface controller is connected to 4 Line, 20 Character LCD display using eleven lines (eight for data and three for controlling the LCD). Four push to on keys (SET, UP, DOWN, and BACK) are connected to the controller which are used for setting the parameters of the sequencer. Two lines are used to connect the sequencer controller serially. When settings are entered using the four keys, at the end of the setting the data is transmitted serially to the sequencer controller. The user interface controller displays information about total current drawn from the main supply individual channel voltage, temperature, and the ON/OFF sequence. The display is updated once every time the data is received from the sequencer controller. The user interface controller displays an error message if it fails to receive data from the sequencer controller within 1000 ms of display screen refresh.

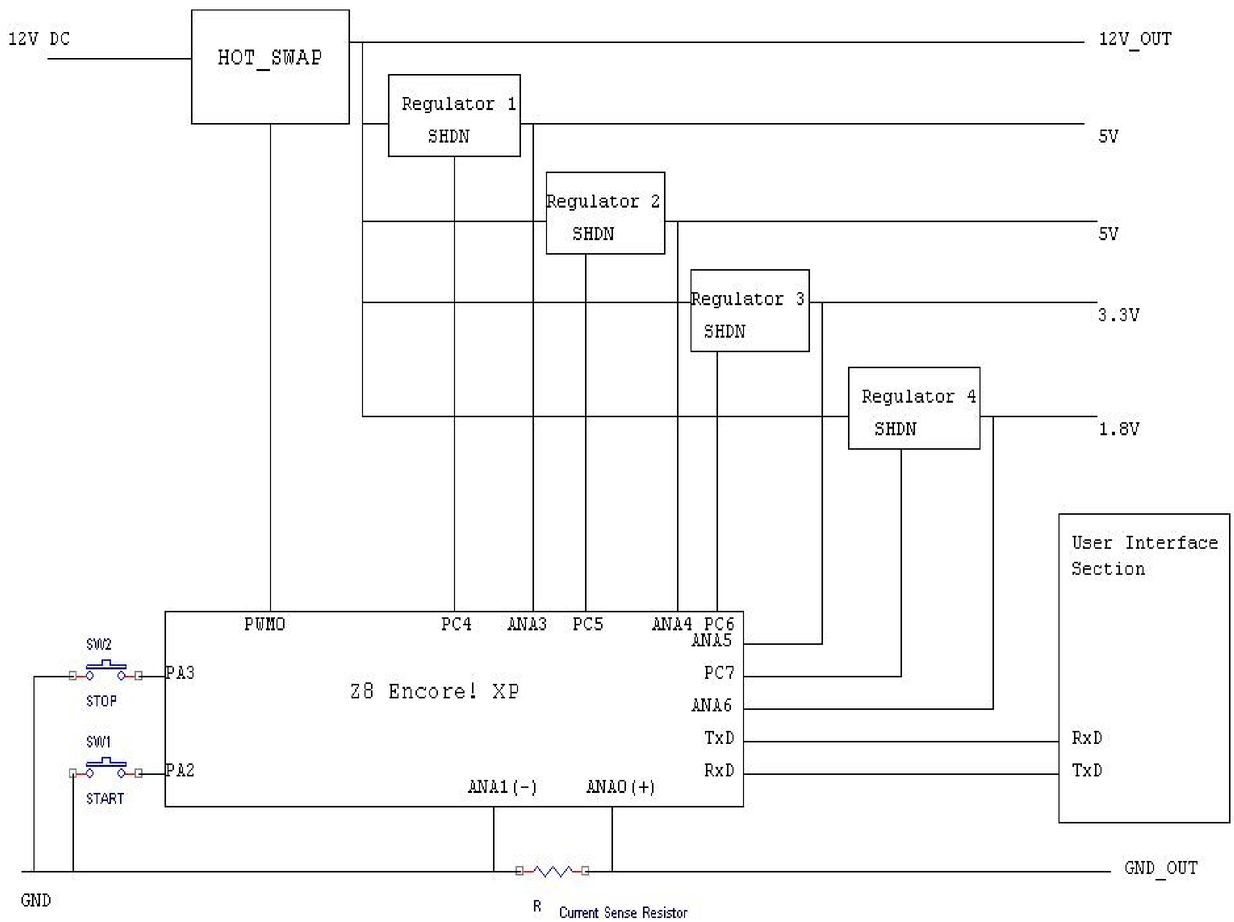


Figure 1. Power Supply Sequencer Block Diagram

Software Implementation

The functionality of the device is divided between two controllers.

1. Sequencer Controller
2. User Interface Controller

Sequencer Controller

The sequencer controller initializes the Timer0 for PWM generation, UART for serial communication at 9600 bps, ADC for voltage, current, and temperature measurement and GPIO for switching the regulators. A set of default values for over voltage, under voltage, over current, over temperature, ON sequence, OFF sequence, delay between sequence, ON Ramp time, OFF Ramp time is stored in the Flash memory of the controller. The sequencer uses these default settings when no user programmed values are available. It then polls for any update in the settings from the user interface controller and stores the information in NVDS and uses for functionality of the sequencer.

Timer0 PWM feature is used to Ramp up the input voltage from 0 to the maximum by varying the duty cycle from 0 to maximum. The frequency of the PWM is maintained at 5 kHz. Among the eight analog input channels, ANA0 and ANA1 are used as a differential amplifier to measure current. ANA3:6 is used for measuring the channel voltages of the switching power supplies. The alarm

High and **Low** enable bits are turned ON for ANA3:6, so in case of any over voltage or under voltage the alarm bits are set which indicates the limits of over voltage and under voltage.

User Interface Controller

After initializing the peripherals, the user interface controller scans the keypad continuously and also updates the LCD display with the information received from the sequencer. When you change the settings using the keypad, the controller checks for a valid input and stores in the controller memory. When all the required settings are completed, a packet of data is sent to the sequencer controller via the UART. The sequencer controller receives the settings and sets the under voltage, over voltage, over current, and temperature limits for operation.

The communication between two controllers is polled and not interrupt driven, so the sequencer places a byte on the UART and waits for response from the display controller for a small duration of CPU clock. The display controller upon receiving a **Start** byte from the sequencer controller returns a control byte back to the sequencer controller. Depending on the control byte the sequencer sends a packet of display data or the settings data. The display controller receives the packet of data. If the display controller does not receive any of the packets for 100 poll then the display is flashed with the string **NO Signal** with the appropriate error flashing in the last line (Rx data error or Rx settings error).

Programming of the Power Supply Sequencer

The code for the sequencer controller or the user interface controller can be flashed by connecting the Zilog debug interface cable to the debug connector J1. Jumper J2 is used to Flash either the display controller or the sequencer controller. Power supply sequencer uses the default settings stored in the Flash memory of the controller when switched ON for the first time. At any point of operation of the sequencer, holding the **STOP** key and pressing the **RESET** will load the default settings.

LCD Display Overview

Power supply sequencer comes with a set of preset values loaded. The startup screen shows the following displays:

ON Sequence Display

Displayed when the sequencer is OFF. Displays four sequence number for four devices in serial order of the devices, see Figure 2.

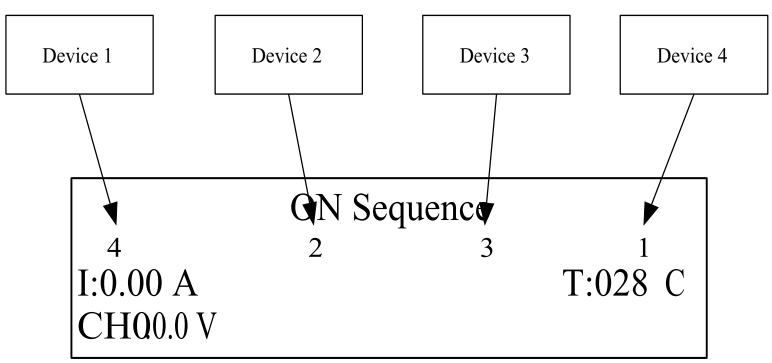


Figure 2. LCD Display (Sequencer is OFF)

In Figure 2, Device 1 will be the 4th to turn ON in sequence, that is, in this case Device 1 will be the last to turn ON and Device 4 will be the 1st to turn ON. Any device, which has the 0 sequence number remains un-altered. More than two devices can have the same priority of switching in a sequence. Devices with the same priority are turned ON at the same time.

OFF Sequence Display

Displayed when sequencer is started. Displays four sequence number for four devices in serial order of the devices, see Figure 3.

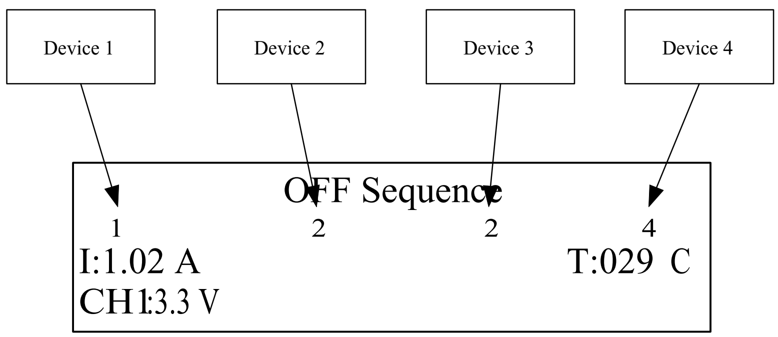


Figure 3. LCD Display (Sequencer is ON)

In Figure 3, Device 1 will be the 1st to turn OFF in sequence, and Device 4 will be the 4th to turn OFF. More than two devices can have the same priority of switching in a sequence. In this case Device 2 and Device 3 will turn OFF at the same time. There is no sequence number 3 hence no device is altered at that sequence level.

> **Note:** *The delay between sequences can be programmed as explained in* Appendix A—Settings for the Power Supply Sequencer *on page 11.*

Current

Displayed in third line, indicates the total current consumed from the power supply input by all the four switching power supplies.

Temperature

Displays the operating temperature of the sequencer controller. In order to measure the total temperature of a system, the design which includes this controller should be housed in a single unit.

Channel Voltage

Displays one of the channel information. The channel monitored keeps rolling from 1 to 4.

Procedure to Operate the Power Supply Sequencer

Follow the steps below to operate the power supply sequencer:

1. Connect the 12 V power input to connector J3 and switch ON the power supply.
2. The LCD display shows the ON sequence, current, temperature, and channel voltage.
3. Set the various parameters for the sequencer (for details on setting the parameters for the sequencer, see Appendix A—Settings for the Power Supply Sequencer on page 11) or hold **Stop** key and press **Reset** button to load default values.
4. After all the parameters are adjusted, press **Start key** to start the sequencer.

5. Now the output voltage at connector J9 slowly ramps up to maximum of 12 V depending on the ON ramp delay setting as shown in the waveform in Figure 4 on page 8.
6. The switching power regulators are turned ON in sequence as set in the ON sequence settings. The delay between the settings is as shown in the waveform in Figure 6 on page 10.
7. If any of the controlled parameters (four voltage levels, current, and temperature) is not within the set value, the display flashes the fault condition and the power supply is shutdown. To remove the fault message press **Stop key**.
8. If the controlled parameters are within limit, the display shows the OFF sequence with the current, temperature, and the channel voltage.
9. The sequencer now monitors the **Stop key**. When the **Stop key** is pressed it sequences OFF the power supplies as set in the OFF sequence settings and ramps down the output voltage at connector J9 to zero as shown in the waveform in Figure 5 on page 9.
10. Now the display shows the ON sequence, current, temperature, and channel voltage.
11. Settings can also be done when the system is turned ON and the implementation is immediate. For more details on individual setting parameters, see Appendix A—Settings for the Power Supply Sequencer on page 11.

Messages Displayed by the Display Unit

NO Signal

If the sequencer is not connected it does not function properly and momentarily, when the sequencer is turned ON/OFF.

End of Data not Detected

This message is displayed if there is an error in data framing.

Under Voltage

This message is displayed when the sequencer is turned ON and the output voltage at any of the output regulators switched ON is lower than the set limit.

Over Voltage

This message is displayed when the sequencer is turned ON and the output voltage at any of the output regulators switched ON is higher than the set limit.

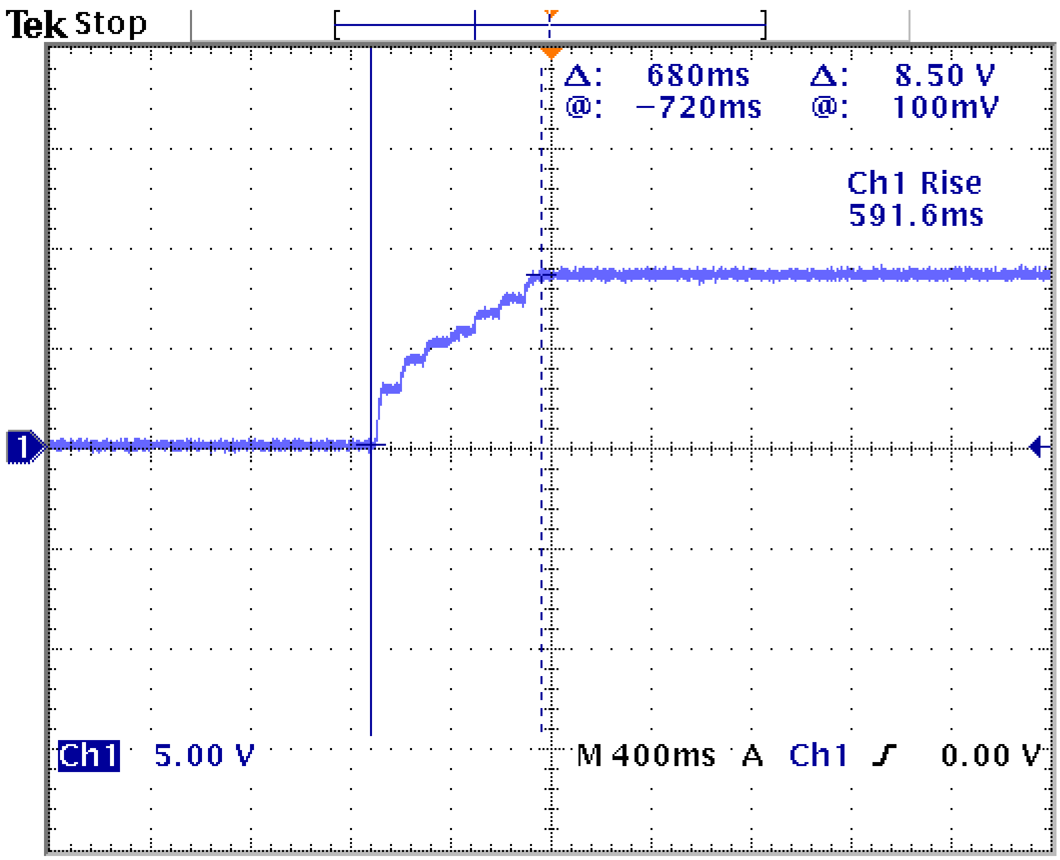
Over Temperature

This message is displayed when the sequencer is turned ON and the ambient temperature exceeds the set limit.

Over Current

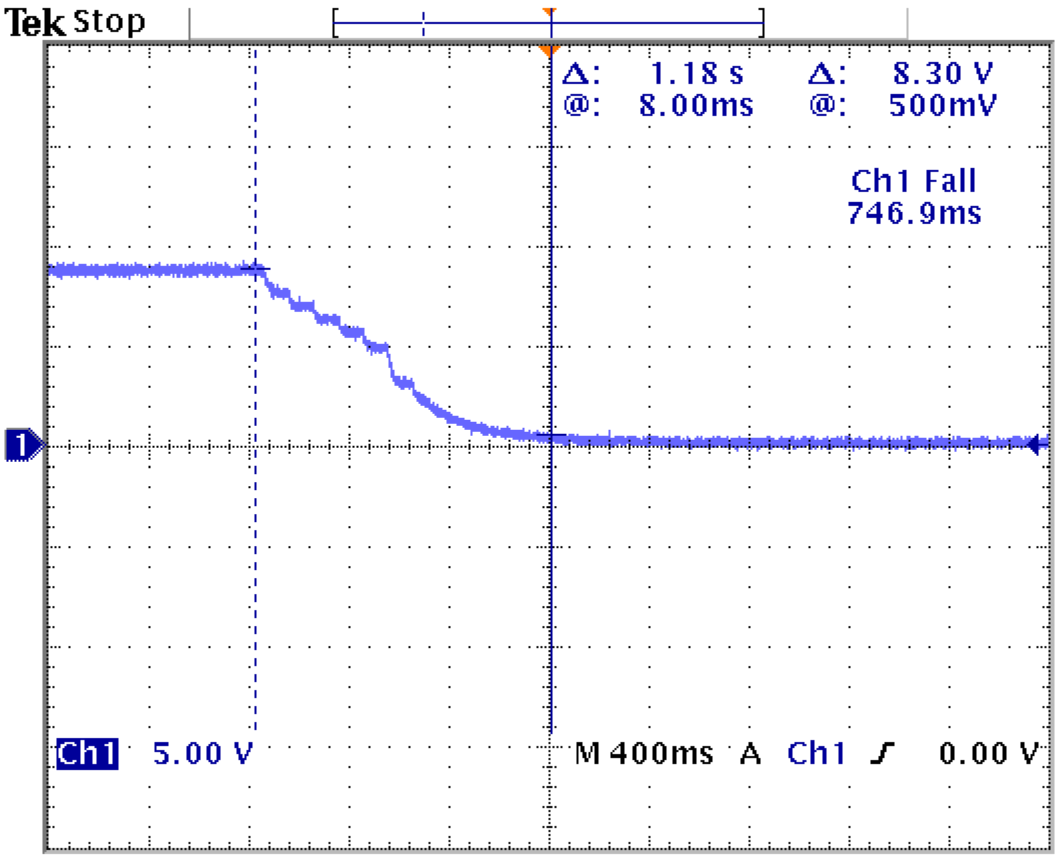
This message is displayed when the sequencer is turned ON and the total current drawn from all the controlled regulators exceeds the set value.

WaveForms



Voltage Ramp up when the sequencer is switched ON at a load current of 200mA

Figure 4. Voltage Ramp Up at 12 V Output Terminal



Voltage Ramp down when the sequencer is switched OFF at load current of 200mA

Figure 5. Voltage Ramp Down at 12 V Output Terminal

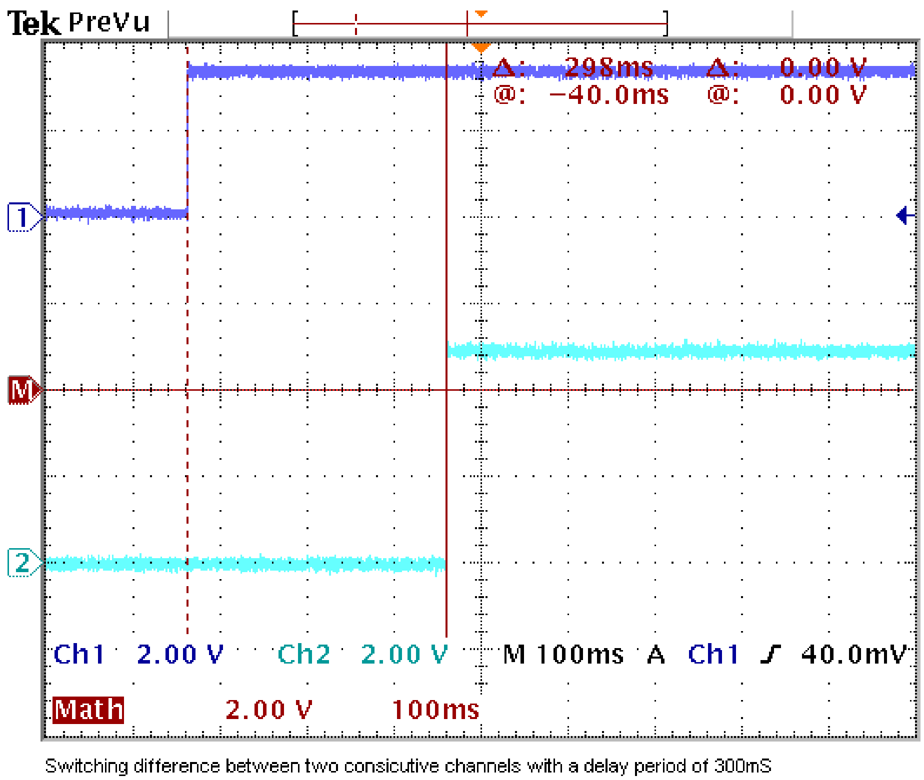


Figure 6. Switching Difference Between Two Consecutive Channels with a Delay of 300 ms

Summary

This application note explains how Z8 Encore! XP® can be used for functions like Hot Swap, sequencing and monitoring of temperature, current, and voltage. The controller provides flexibility and ease in operation by introducing a number of required functionality by means of programming the device. UART communication is implemented and connected to PC to update the monitored parameters. Also the device can be programmed for additional options in sequencing and controlling unlike a dedicated hardware for controlling.

References

The documents associated with Z8 Encore! XP, available on www.zilog.com are provided below:

- Z8 Encore! XP® F082A Series Product Specification (PS0228)
- Reading Temperature Using the Z8 Encore! XP® MCUs Application Note (AN0191)
- Using Z8 Encore! XP® Microcontroller for Current Measurement Application Note (AN0193)
- ADC Compensation in Z8 Encore! XP® MCUs Application Note (AN0284)
- NVDS Operation in the Z8 Encore! XP® F042A Series Microcontroller Application Note (AN0293)
- Technique for Measuring System Temperature Using On-chip Temperature Sensor of the Z8 Encore! XP® Application Note (AN0294)

Appendix A—Settings for the Power Supply Sequencer

The settings menu is displayed when the **SET** key is pressed in the idle display mode. The settings menu has ten menu items, each of the menu item is programmed by pressing the **SET** key. You can move between menu items by pressing the increment/decrement button. When the desired menu item is selected press **SET** key to program the particular menu item. Press increment/decrement button to program the parameters for the menu item. When done with programming of the parameters press **Esc** key. When the unit displays settings menu, pressing the **Esc** key prompts for save and exit. If the settings has to be saved press **SET** key else press **Esc** key to exit without saving the recently done settings. The changed parameters can also be saved by moving to the save and exit menu item of the settings menu.

ON Sequence

Four sequence numbers (0 to 4) are displayed which corresponds to the devices in serial from left to right. Any of the two devices can have the same sequence number. Sequence number 0 is also a valid for any device, as this device remains unaltered in sequencing.

OFF Sequence

Four sequence numbers (1 to 4) are displayed which corresponds to the devices in serial from left to right. Any of the two devices can have the same sequence number. Sequence number 0 is invalid as the sequencer powers OFF the input voltage to the power regulators.

Sequence Delay

This is the delay introduced between the sequencing of the devices. The first sequence delay from left corresponds to the delay between sequence 1 and sequence 2 levels. The number extends form 1 to 10 in terms of 100 ms.

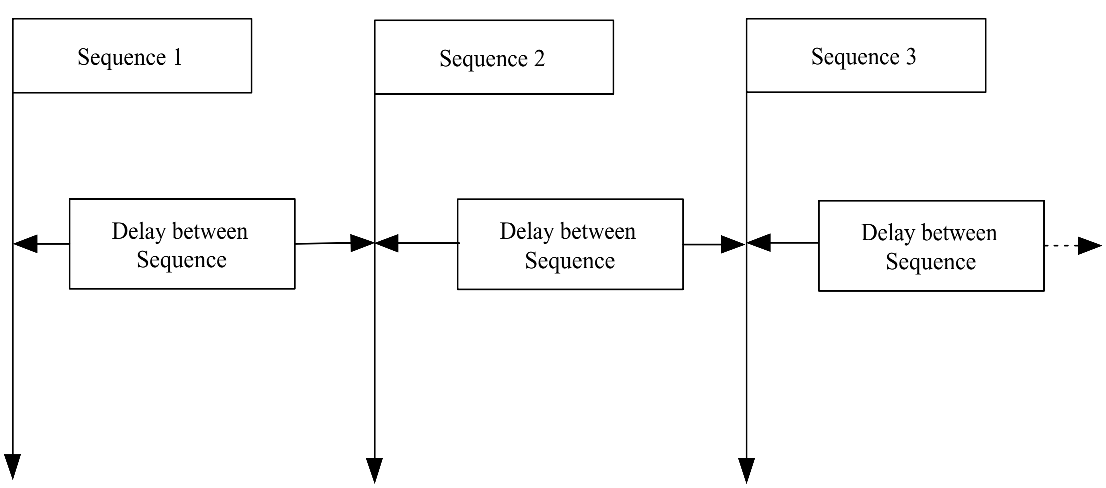


Figure 7. Delay Between Sequencing of Power Regulators

Current

Set the maximum value of current that has to be regulated. If the actual current exceeds the set value, the sequencer sequences OFF the power and ramps down according to the programmed values.

Temperature

Set the maximum value of temperature that has to be regulated. If the actual temperature measured by the sequencer exceeds the set value the sequencer sequences OFF the power and ramps down according to the programmed values.

Under Voltage

The voltage limit for under voltage is set in terms of the percentage of the voltage monitored on the particular channel. The minimum limit is 75%. Any voltage can be brought down to 1 V level and applied for the ADC converter of the sequencer. The voltage to be displayed on that channel has to be appropriately multiplied by the corresponding voltage multiplication factor, which is included in the header file `user.h`.

Over Voltage

The voltage limit for under voltage is set in terms of the percentage of voltage monitored on the particular channel. The maximum limit is 125%.

ON RAMP Delay

This is the delay to start the sequencer from shutdown to the maximum value of applied voltage. The PWM feature is used to ramp up the voltage from 0 to the maximum value of the applied voltage.

OFF RAMP Delay

This is the delay to shutdown the sequencer from ON state. The PWM feature is used to ramp down from the maximum value of the applied voltage to zero.

Save and Exit

Press **SET** key to enter the menu and press **SET** key once again to save the settings, else press **Esc** key to exit without saving the settings. **Save** and **Exit** function can be invoked at any time during the settings menu is displayed by pressing the **Esc** key.

Figure 8 displays the flowchart for setting the sequencer parameters.

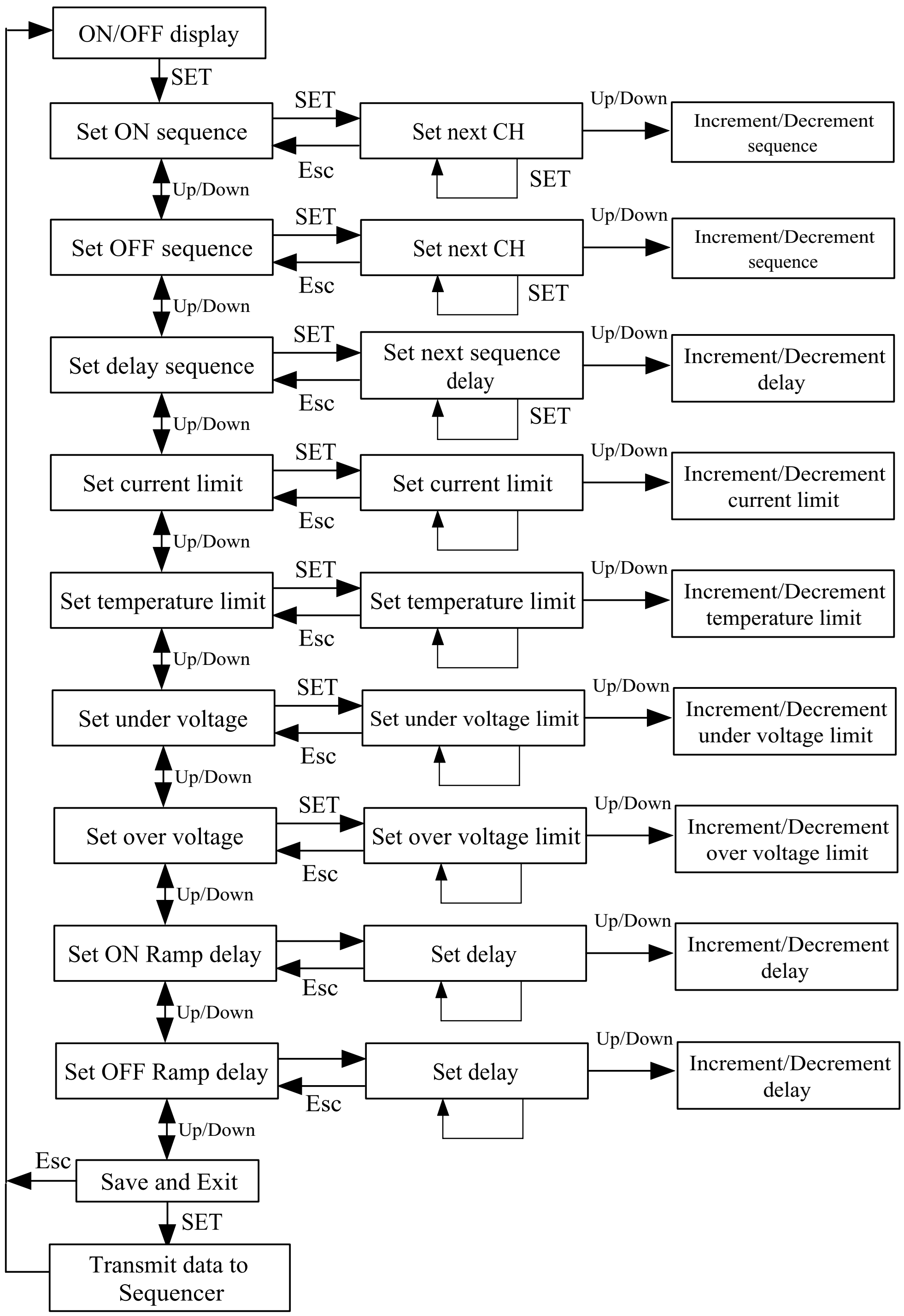


Figure 8. Flowchart for Setting Sequencer Parameters

Appendix B—Schematic and Board Diagrams

Appendix B displays the Schematic and Board Diagrams for the Power Supply Sequencer.

Schematic Diagrams

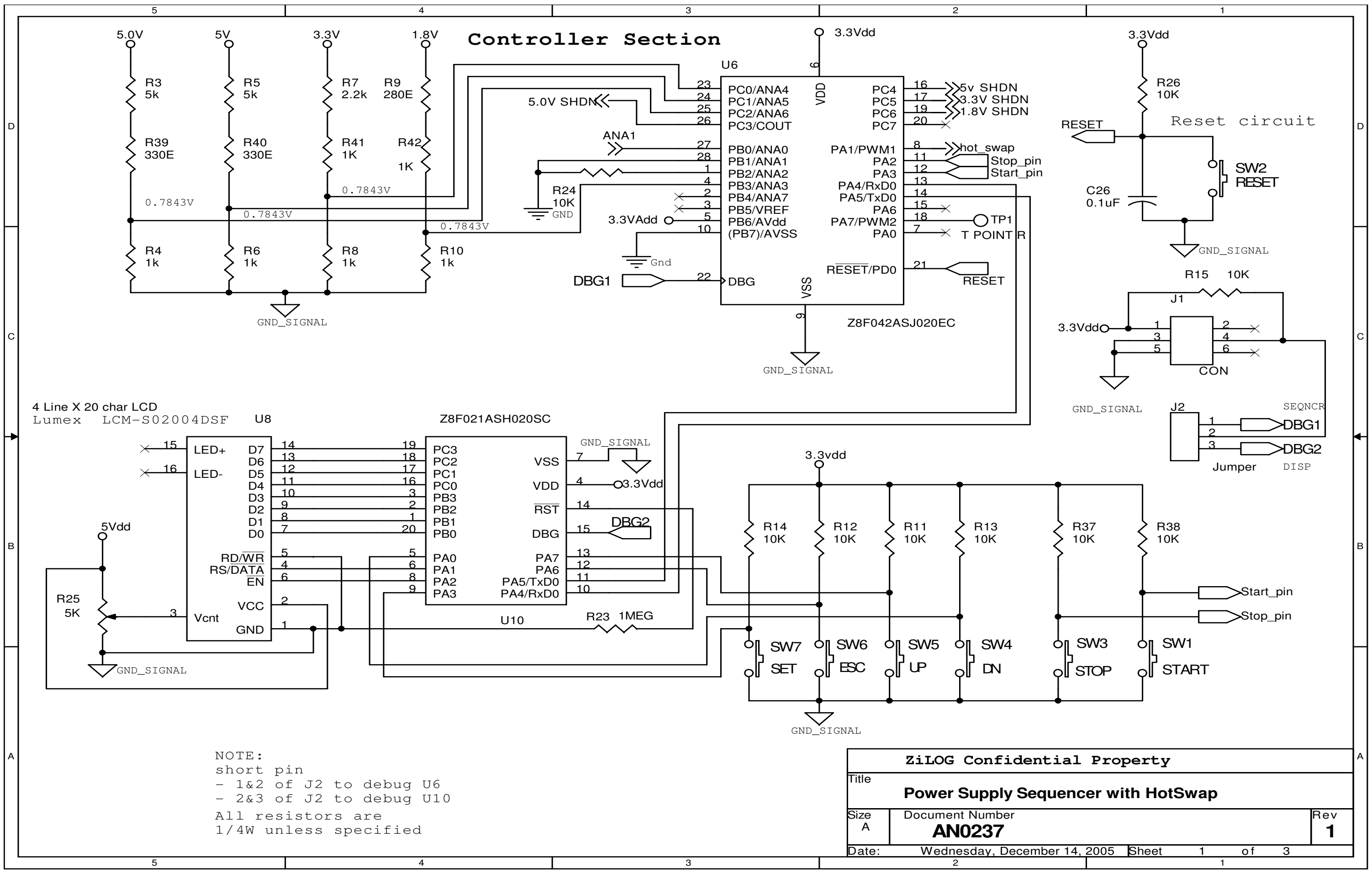


Figure 9. Schematic of Controller Section

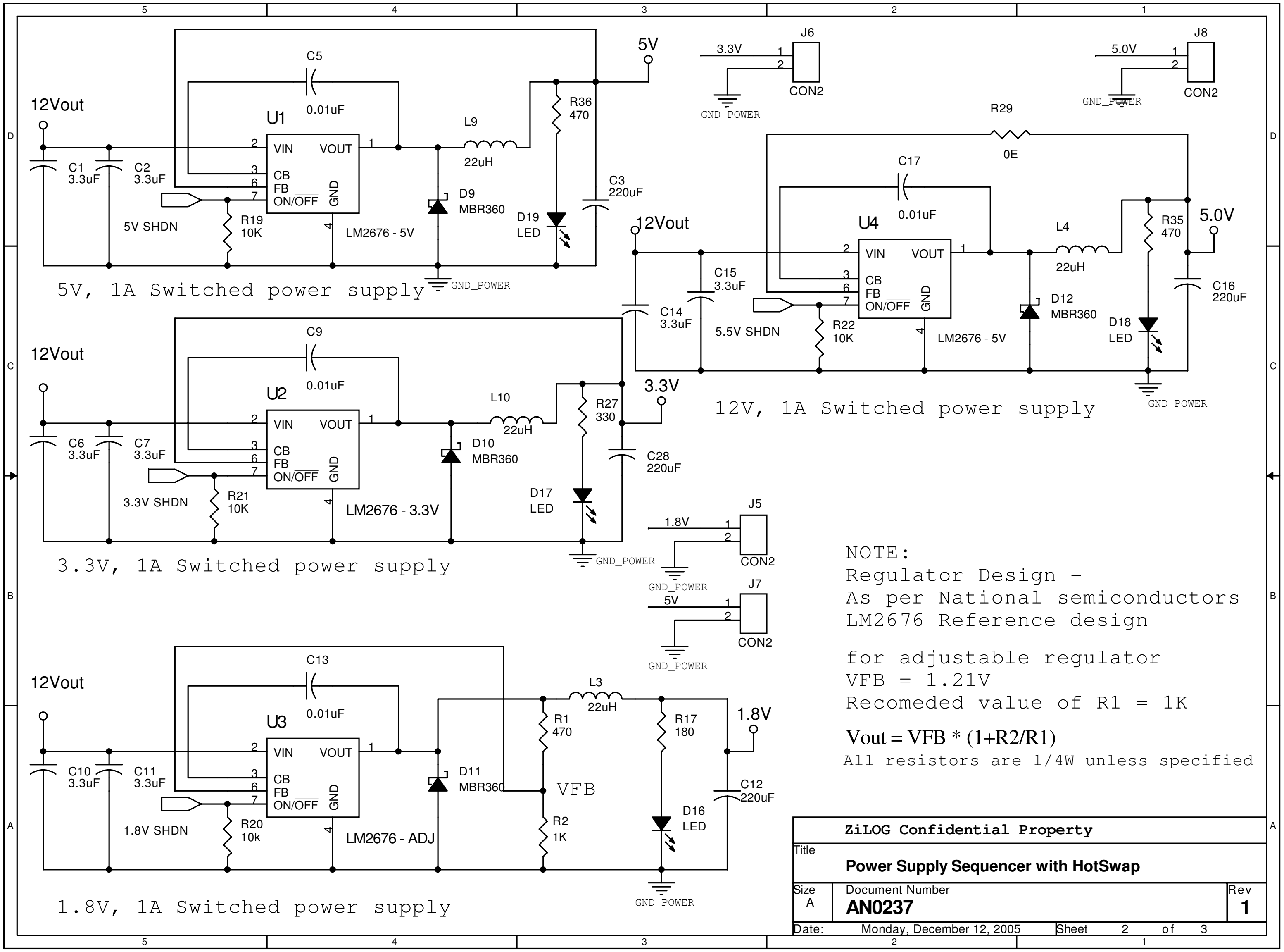


Figure 10. Schematic of Power Regulator Switching Section

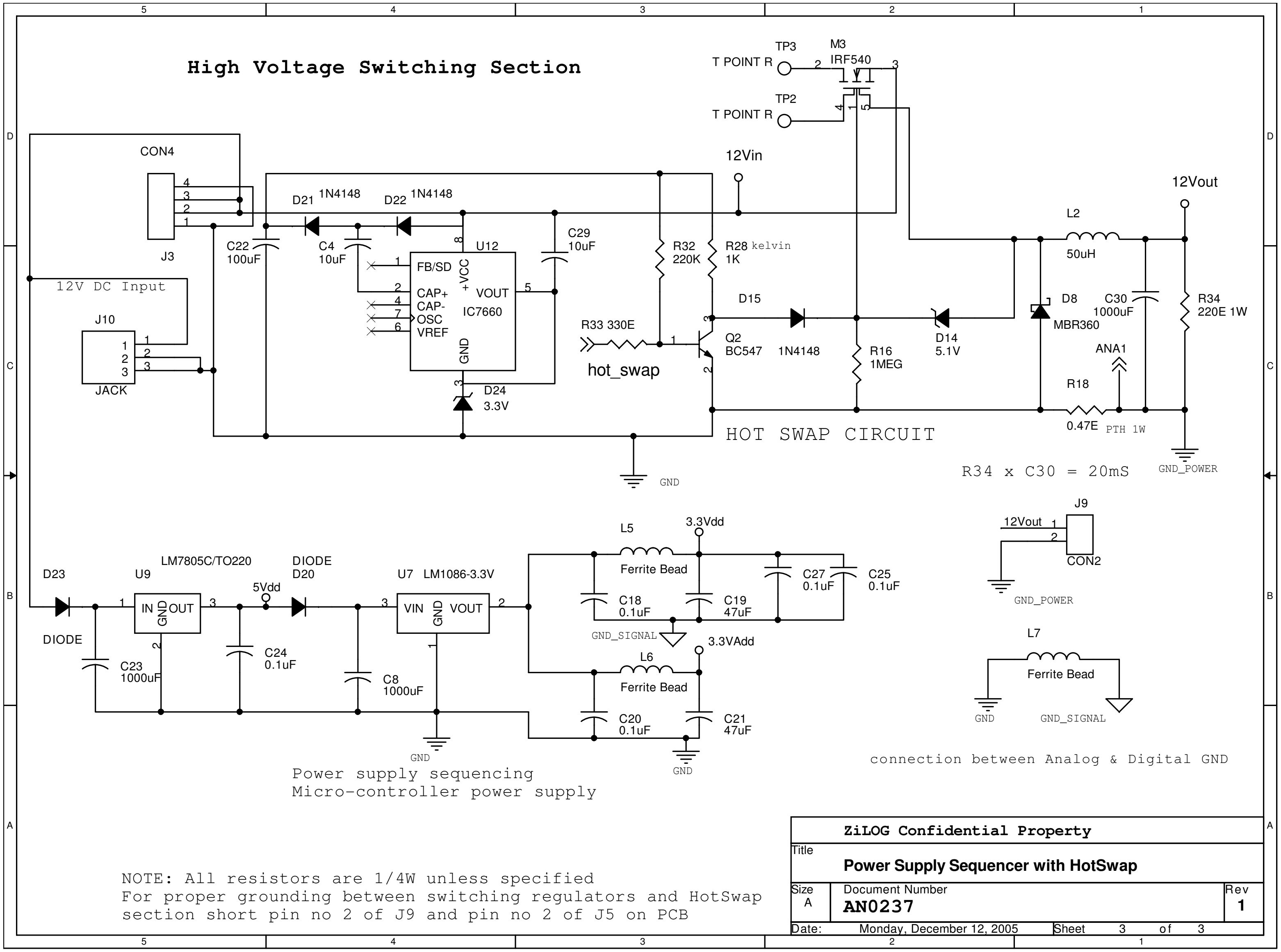


Figure 11. Schematic of High Voltage Switching Section

Board Diagrams

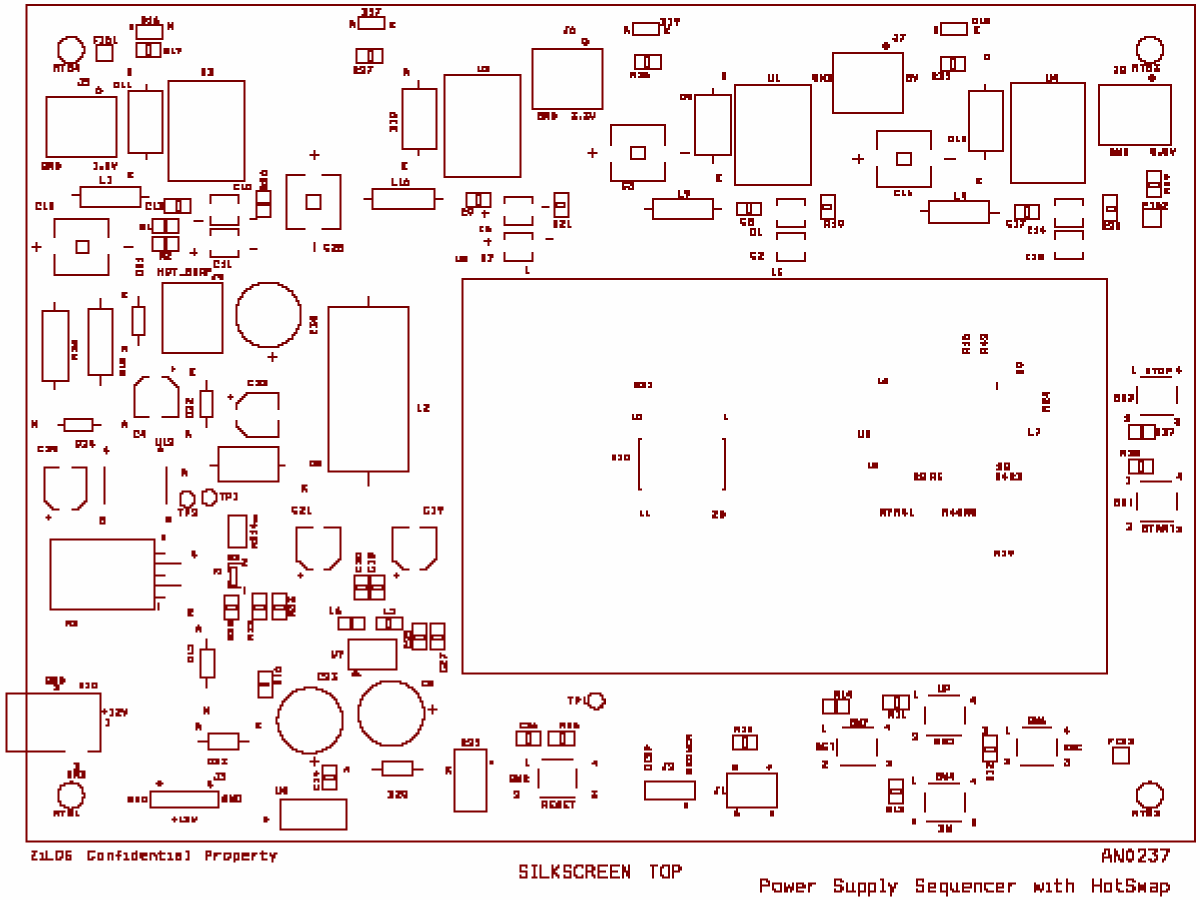


Figure 12. Silk Screen

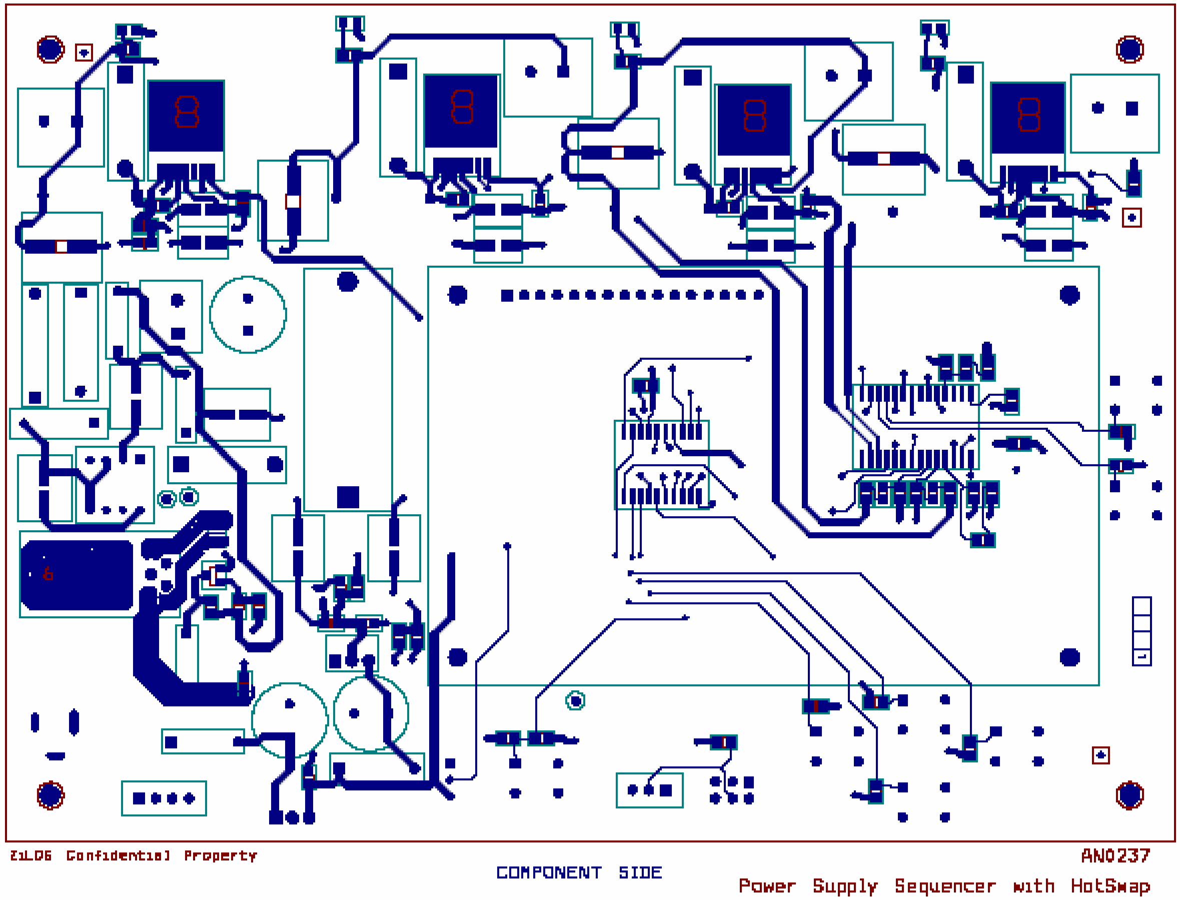


Figure 13. Component Side

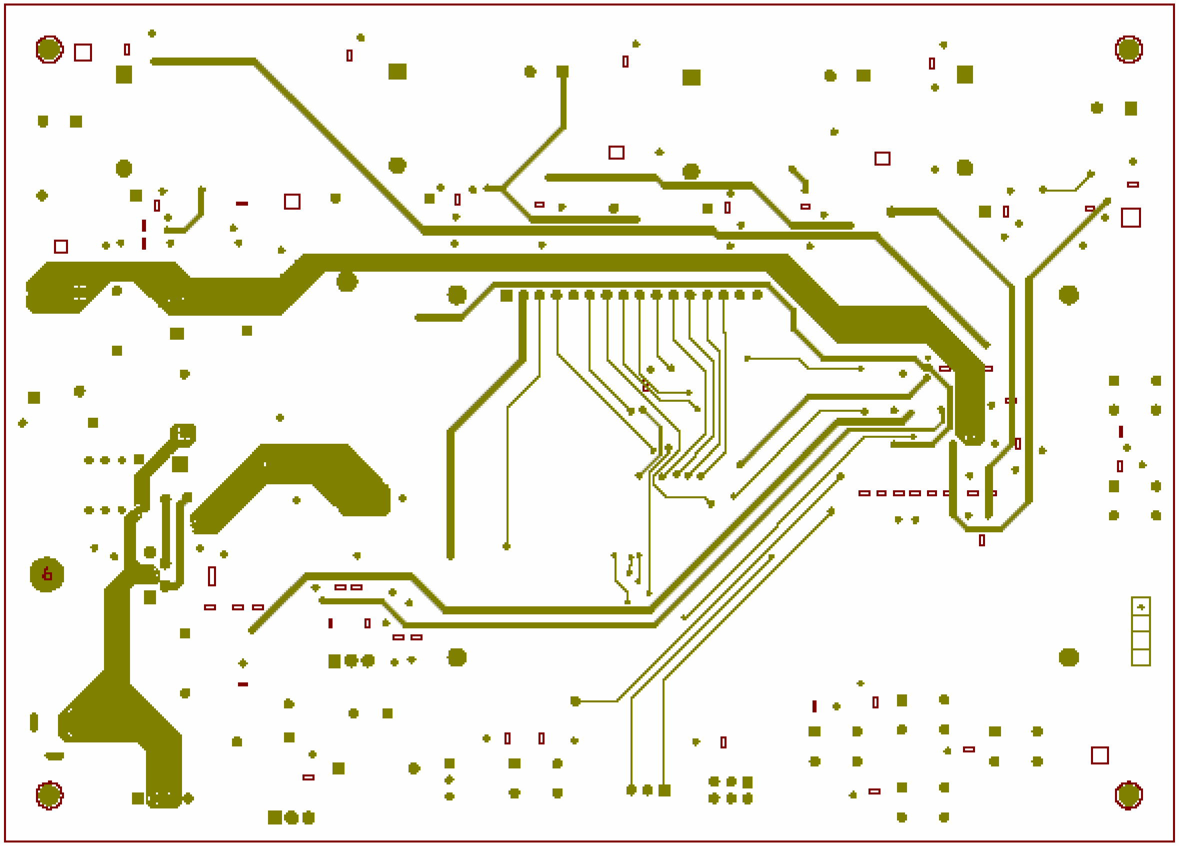


Figure 14. Solder Side

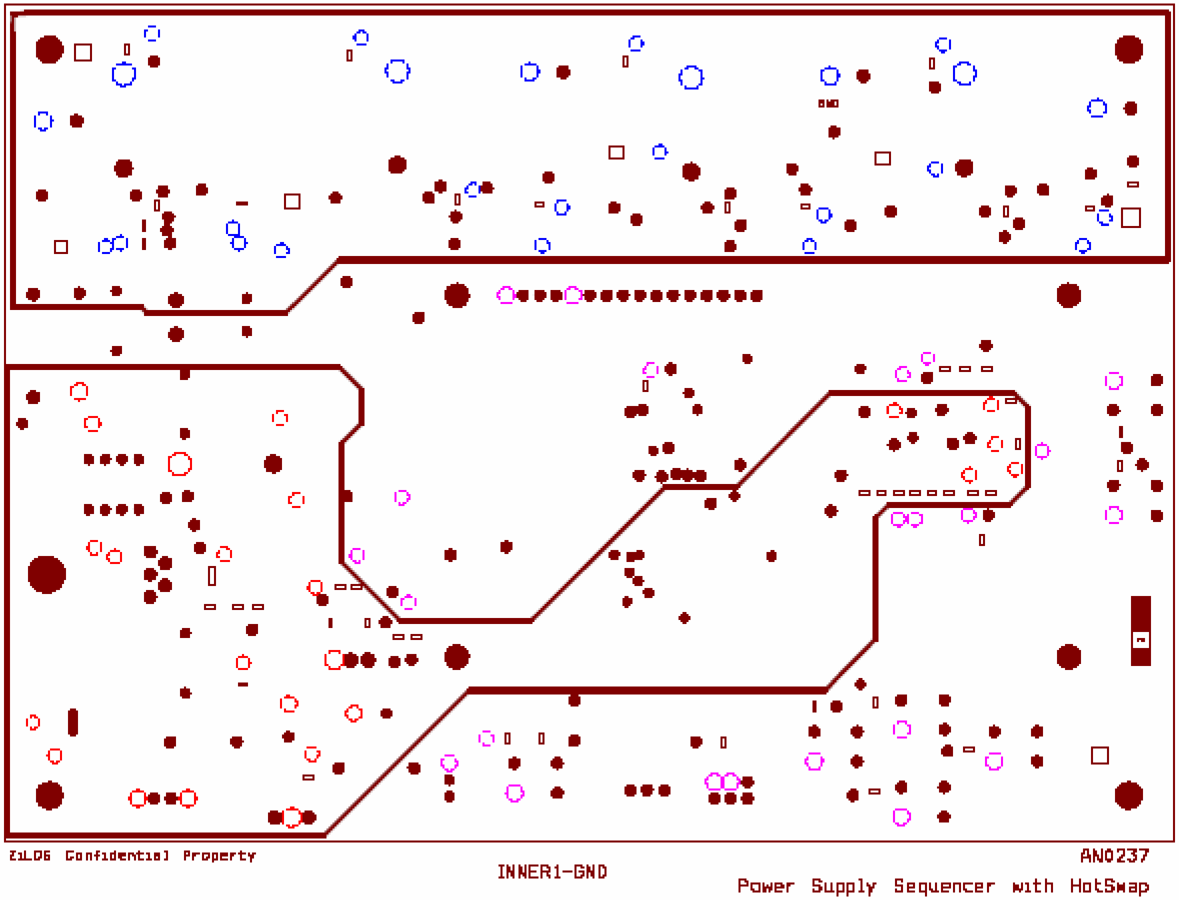


Figure 15. Inner1-Ground

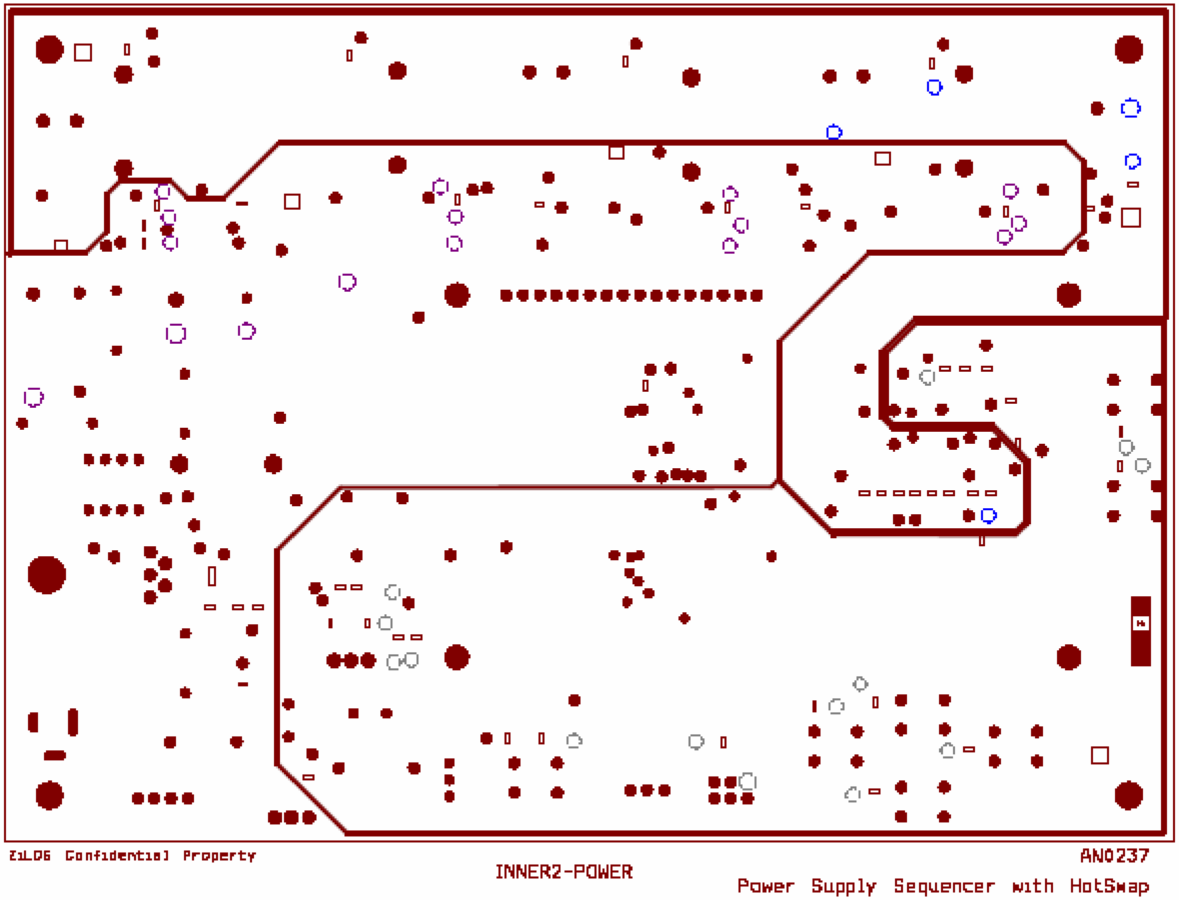


Figure 16. Inner2-Power

Appendix C—Bill of Material

Table 1 lists the Bill of Material for the Power Supply Sequencer.

Table 1. Bill of Material

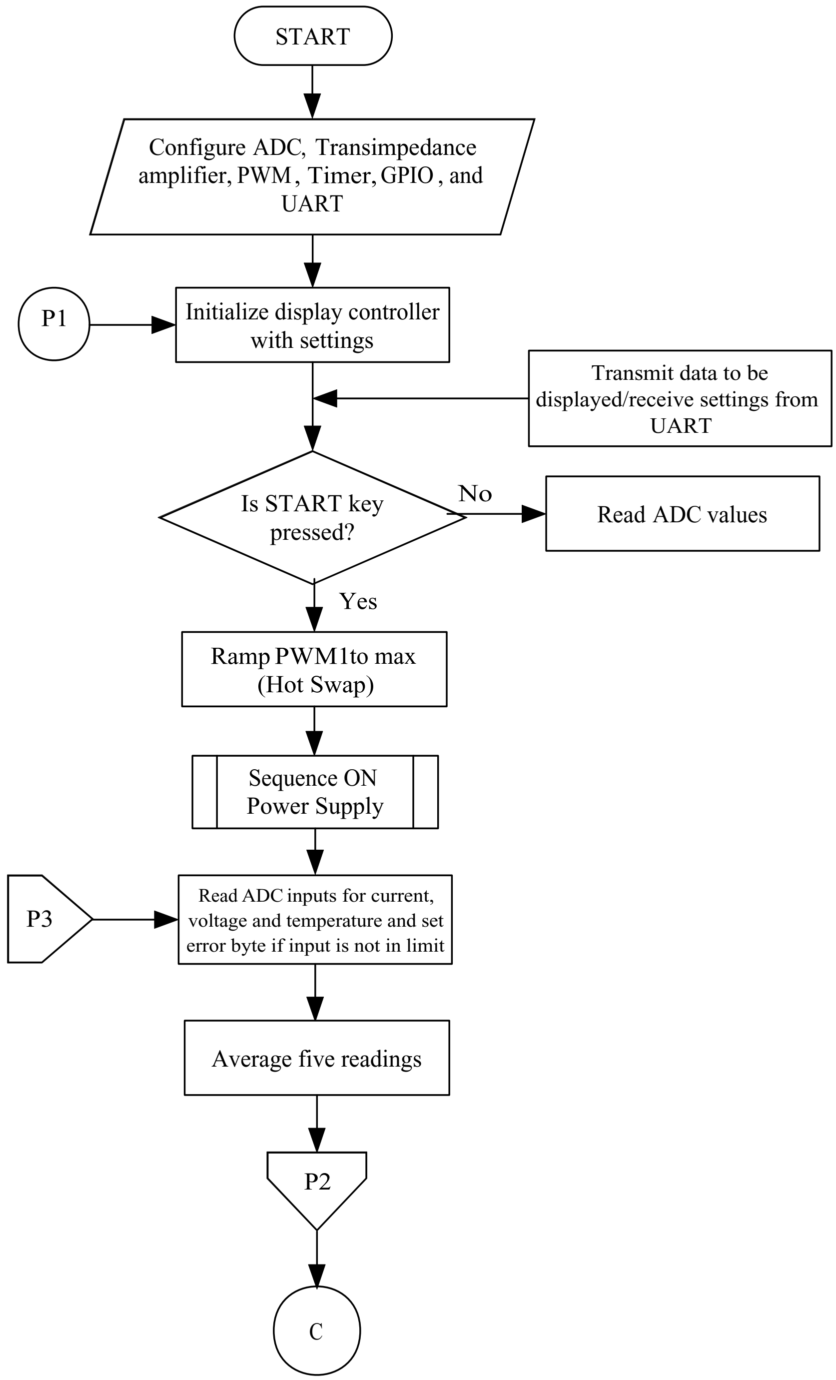
Item	Quantity	Value/Part Number	Part Reference
1	8	3.3 µF	C1, C2, C6, C7, C10, C11, C14, C15
2	4	220 µF	C3, C12, C16, C28
3	2	10 µF	C4, C29
4	4	0.01 µF	C5, C9, C13,C17
5	2	1000 µF	C8, C30
6	3	0.1 µF	C18, C20, C26
7	2	47 µF	C19, C21
8	1	100 µF	C22
9	1	1000 µF	C23
10	3	0.1 µF	C24, C25, C27
11	5	MBR360	D8, D9, D10, D11, D12
12	1	5.1 V	D14
13	1	1N4148	D15
14	4	LED	D16, D17, D18, D19
15	2	DIODE	D20, D23
16	2	1N4148	D21, D22
17	1	3.3 V	D24
18	1	CON	J1
19	1	Jumper	J2
20	1	CON4	J3
21	5	CON2	J5, J6, J7, J8, J9
22	1	50 µH	L2
23	4	22 µH	L3, L4, L9, L10
24	3	Ferrite Bead	L5, L6, L7
25	1	IRF540	M3
26	1	BC547	Q2
27	8	1K	R1, R4, R6, R8, R10, R28, R41, R42
28	3	470	R2, R35, R36

Table 1. Bill of Material (Continued)

Item	Quantity	Value/Part Number	Part Reference
29	2	5k	R3 R5
30	1	2.2k	R7
31	1	280E	R9
32	13	10K	R11, R12, R13, R14, R15, R19, R20, R21, R22, R24, R26, R37, R38
33	1	1MEG	R16
34	1	180	R17
35	1	0.01E	R18
36	2	1K	R23, R29
37	1	5K	R25
38	1	330	R27
39	1	22K	R32
40	3	330E	R33, R39, R40
41	1	220E 1W	R34
42	1	START	SW1
43	1	RESET	SW2
44	1	STOP	SW3
45	1	DN	SW4
46	1	UP	SW5
47	1	ESC	SW6
48	1	SET	SW7
49	3	T POINT R	TP1, TP2, TP3
50	2	LM2676 - 5 V	U1, U4
51	1	LM2676 - 3.3 V	U2
52	1	LM2676 - ADJ	U3
53	1	Z8F042ASJ020EC	U6
54	1	LM1086-3.3V	U7
55	1	4 Line X 20 char LCD	U8
56	1	LM7805C/TO220	U9
57	1	Z8F021ASH020SC	U10
58	1	ICL7660	U12

Appendix D—Flowcharts

Figure 17 displays the main program of the power supply sequencer.



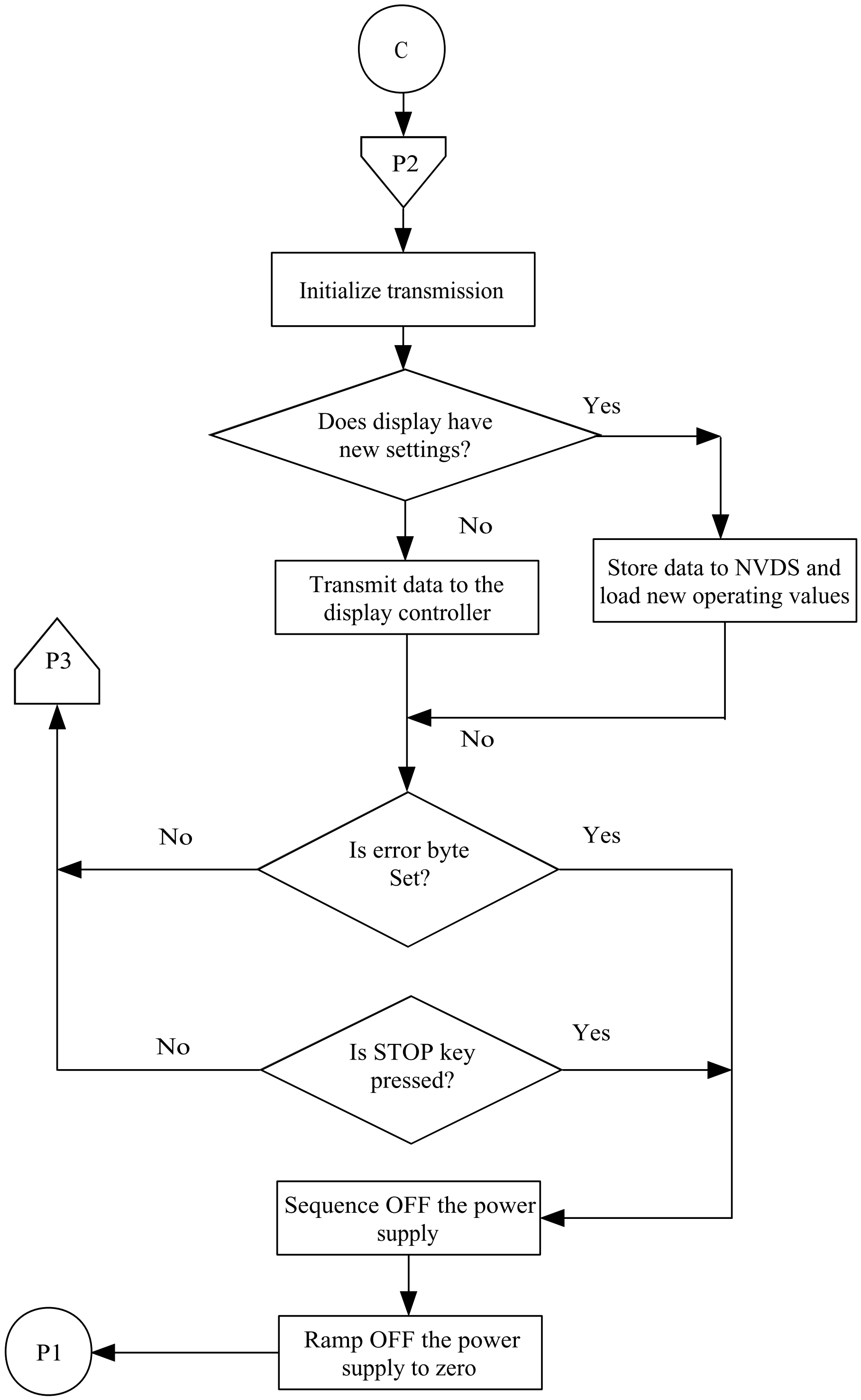


Figure 17. Power Supply Sequencer Flowchart

Figure 18 displays the display interface of the sequencer.

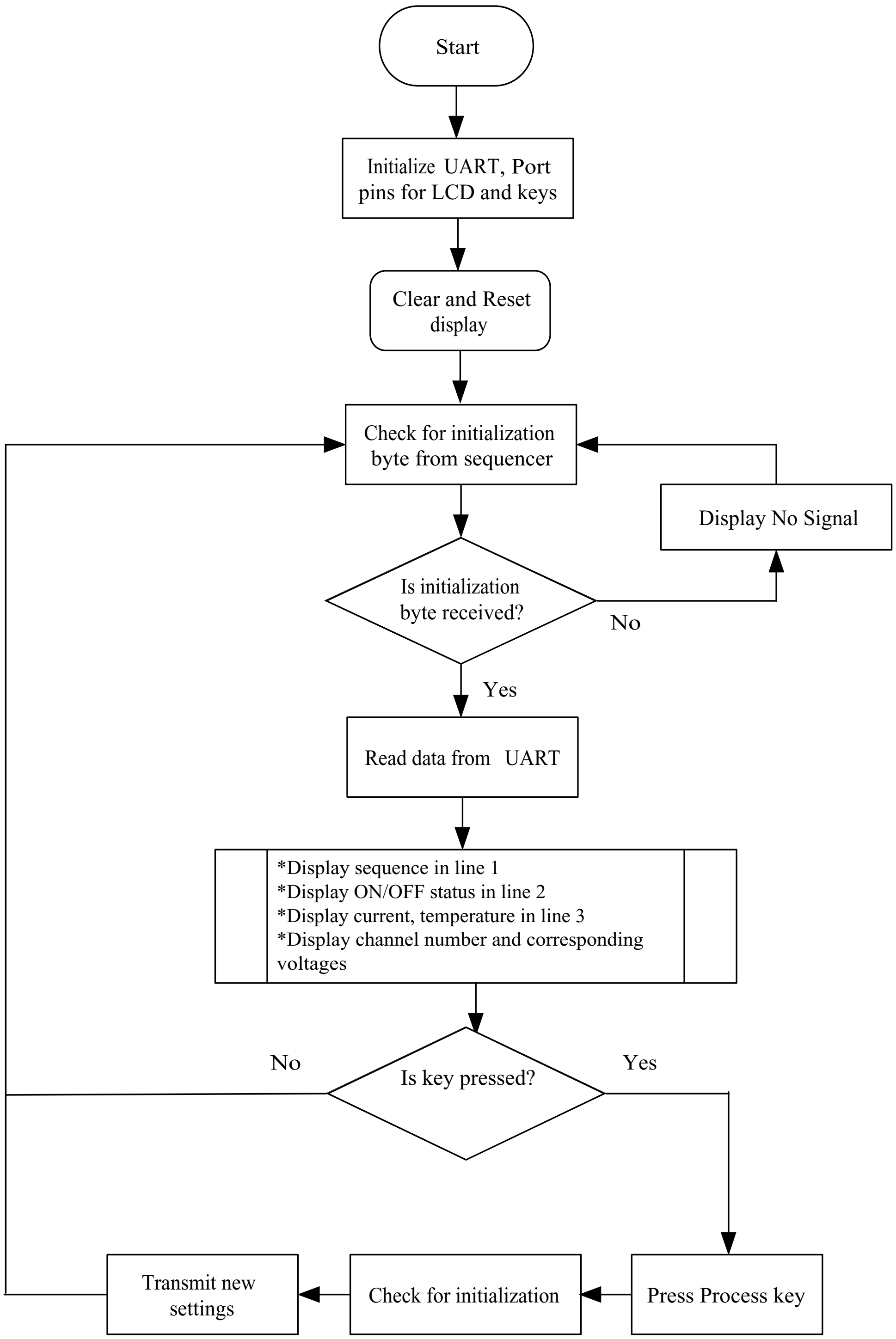


Figure 18. Display Interface of the Sequencer

Warning: DO NOT USE IN LIFE SUPPORT

LIFE SUPPORT POLICY

ZILOG'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF ZILOG CORPORATION.

As used herein

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

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