HASP Payload Specification and Integration Plan

Payload Title: HELIOS

Payload Class: Small [✓ Large] (circle one)

Payload ID: 10

Institution: University of Colorado at Boulder

Contact Name: Gabrielle Massone

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Contact E-mail: gabrielle.massone@colorado.edu

Submit Date: June 22, 2012

I. Mechanical Specifications:

A. Measured Weight of the Payload

Mass Budget

Component	Mass (kg)
Structure	
Electronics Plate	2.0
SHAIRC Mounting Plate	1.9
Side Plates	2.2
Angle Iron	.72
Computing and Electrical	
Motherboard	.25
Microcontrollers	.03
Misc. Electronics	.1
Solid State Drive	.06
ADCS	
Stepper Motors	1.1
Photodiodes	.12
Bearing	.009
Turntable	.25
Chain Assembly	3.1
Science	
Cameras	.53
Telescope Barrels	.17
Optics	.04
Integration Plate	.5
Total	**13.079 kg**

As the payload is assembled, the mass will be continually reassessed to ensure it remains below our 20 kg maximum.

B. Mechanical Drawings:

The "static" part of the structure (which encompasses everything *not* on the rotary table) lies entirely within the dimensional constraints found in the HASP Student Payload Interface Manual. Figure 1, below, was copied directly from the manual.

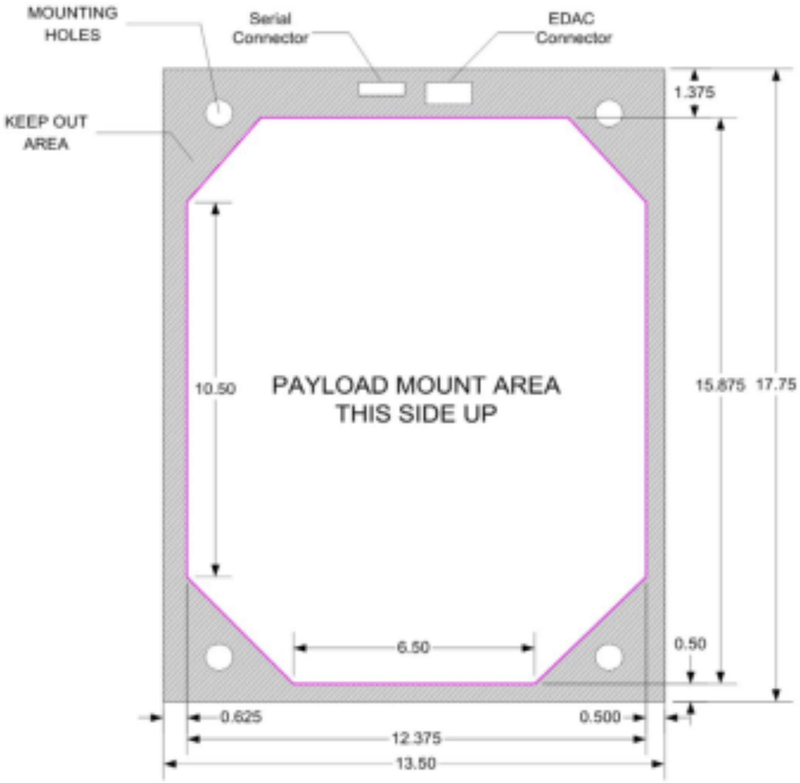


***Figure 1**. Mounting Plate, as defined by the Payload Interface Manual*

The static housing skirt of our payload measures 30 x 38 x 30 cm. To accommodate the additional height of the rotating platform and telescope above, we request a height extension of 8.5 cm. Justification for the height extension can be found at the end of this section. Should the height extension not be granted, we have designed our structure to be easily recut and adapted to fit a smaller volume. The structure mounts to the mounting plate via angle irons bolted on the interior side of each truss.

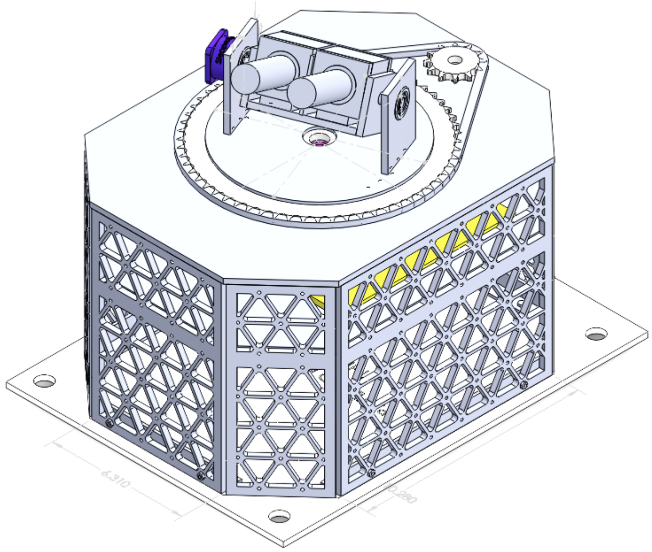


Figure 2. Un-dimensioned perspective view of the payload situated on the mounting plate.

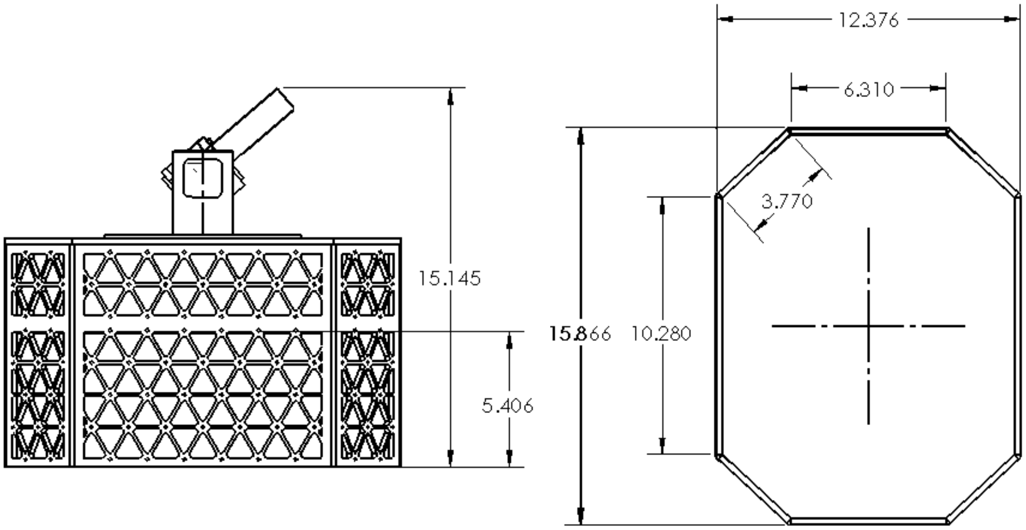


Figure 3. Dimensioned view (inches) of the payload illustrating height (left) and bottom footprint size (right)

Special Request: Height Extension Justification

In order to ensure that HELIOS's science objectives can be achieved, solar viewing time must be maximized. Assuming no line of sight interference from adjacent payloads, HELIOS will be able to view the sun for an estimated 8-10 hours during float. In order to maintain this viewing window throughout the duration of float, HELIOS has requested a height extension above the given 30 cm, to a total height of

38.5 cm. If HELIOS were not granted the height extension, there is the possibility of adjacent payloads blocking up to 17 degrees off of horizontal of HELIOS's field of view, potentially reducing viewing time by up to 1.1 hours upon sunrise and another 1.1 hours upon sunset. This would equate to an estimated loss of up to 28 percent of data recorded by the cameras.

If the height extension were granted, adjacent payload would not interfere with HELIOS's line of sight until 1.3 degrees below horizontal, thus mitigating all possible line of sight inference caused by adjacent payloads.

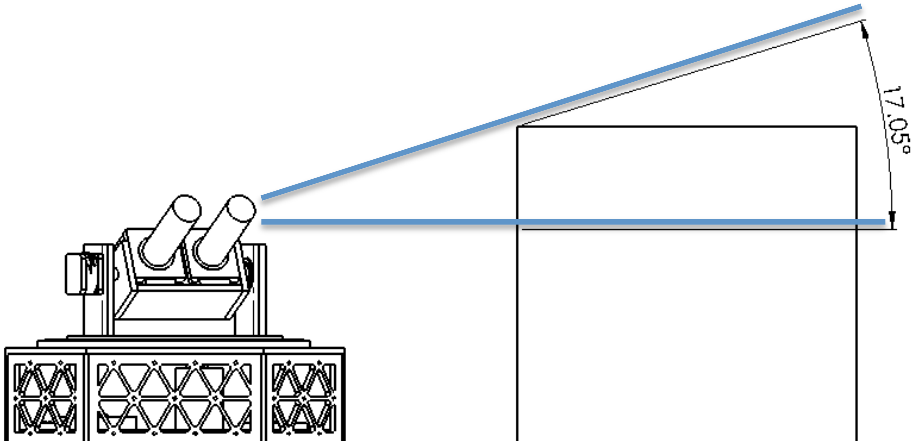


Figure 4. *Drawing with relative payload heights without height extension showing field of view obstructure of over 17°*

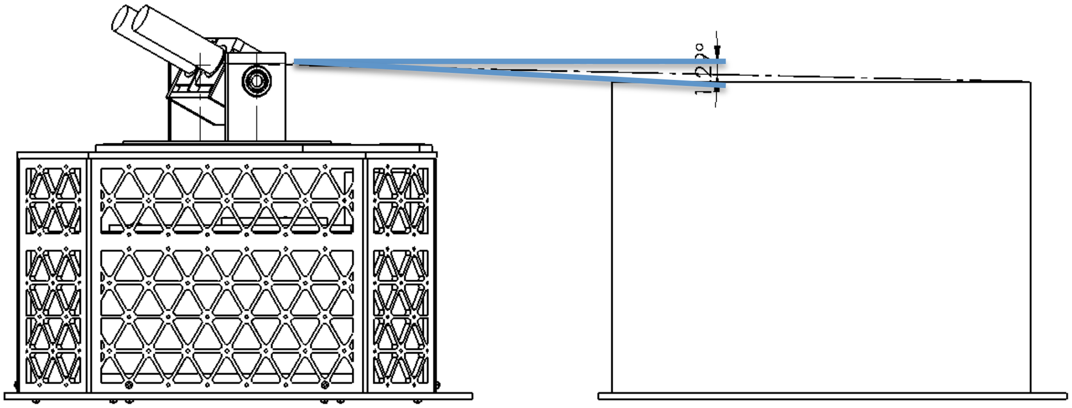


Figure 5. *Drawing Showing Line of Sight with Height extension granted. No adjacent payload interference until 1.3° below horizontal*

C. If you are flying anything that is potentially hazardous to HASP or the ground crew before or after launch, please supply all documentation provided with the hazardous components (i.e. pressurized containers, radioactive material, projectiles, rockets…)

No hazardous materials are present on our payload.

D. Other relevant mechanical information

The HELIOS payload features a rotating platform and a telescope capable of pitching up and down. All motion is driven by two stepper motors and stepper motor drivers, controlled via a motor board (see appendices and attached files). For yaw rotation, a single stepper motor drives a chain drive consisting of two sprockets in a 5:1 ratio. The stepper motor executes half steps (0.9º), which when combined with the sprocket ratio allows for .18º of movement of the platform per step. For pitch control, an identical stepper motor is mounted to the pitch arms. The stepper motor turns an aluminum rod connected to the telescopes mounting bracket, allowing the telescope to pitch upwards or downwards with each step.

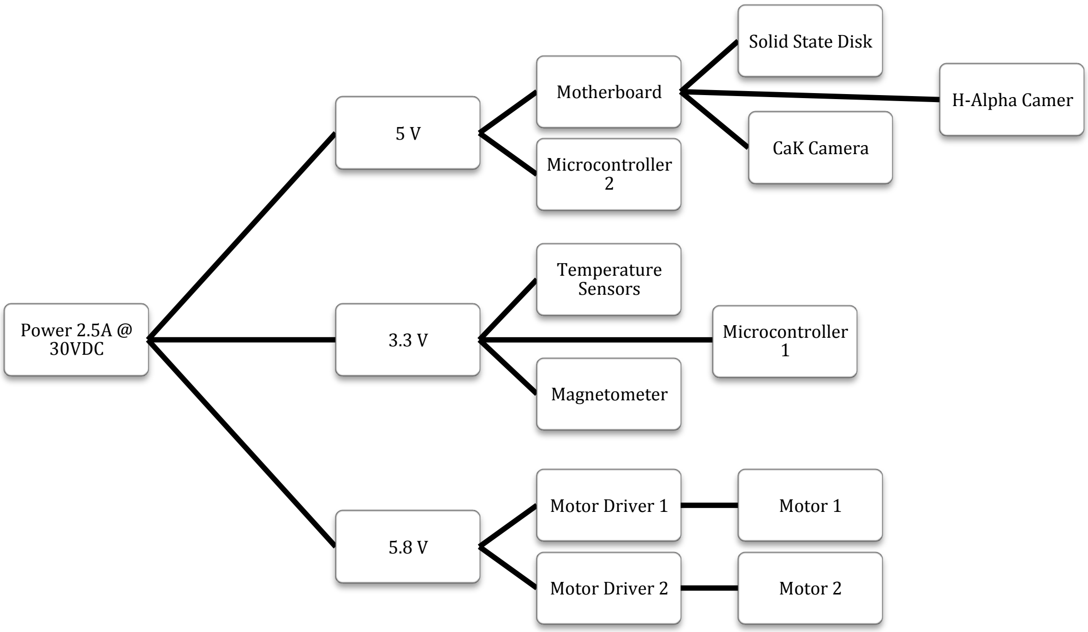
At no time does any part of the rotating platform and telescope extend sideways beyond the footprint of the payload. The height of the system will be dependent on whether or not the height extension is granted; in either scenario, the rotating platform and telescope will remain entirely within the approved volume.

II. Power Specifications:

A. Measured current draw at 30 VDC

1.8 A - 2.0 A

B. If HASP is providing power to your payload, provide a power system wiring diagram starting from pins on the student payload interface plate EDAC 516 connector through your power conversion to the voltages required by your subsystems.



Above is the anticipated flow of power throughout our payload. For detailed power schematics, please refer to the appendices and attached files.

C. Other relevant power information: None

III. Downlink Telemetry Specifications:

A. Serial data downlink format: Stream [✓ Packetized] (circle one)

B. Approximate serial downlink rate (in bits per second)

During one hour of flight, the maximum amount of data we expect to downlink is 4 small log files, which average around 8,192 bytes each, two medium images which will be 65,548 bytes each, and 60 status packets, which are 100 bytes each. This comes to a total of 169,864 bytes per hour or 683 bits per second.

C. Specify your serial data record including record length and information contained in each record byte.

Status Record

Byte	Description
1	Record Identification/type
2-5	Timestamp
6-7	Record size
8	Least significant 8 bits of the record checksum
9-28	10 temperature sensor readings
29-60	Photodiode readings
61-65	Computer process statuses
66-67	Yaw and pitch information (relative to platform)
68-69	Yaw and pitch information (absolute)
70	Last major system event (entered sleep mode, system restart, etc)
71	Error codes present
72	Last command uplinked
73	Current attitude control mechanism
74-75	Motor step sizes
76	Current highest priority process
77-100	Space for extra downlinked data *Please note that if the decision is made to add any additional formatting to make the raw record more readable on the ground, the record size would likely double

Text Record

Byte	Description
1	Record Identification/type
2-5	Timestamp
6-7	Record size

8	Least significant 8 bits of the record checksum
9-end	Text logs from the system

Image Record

Byte	**Description**
1	Record Identification/type
2-5	Timestamp
6-7	Record size
8	Least significant 8 bits of the record checksum
9-10	Number of horizontal pixels
11-12	Number of vertical pixels
13-end	Image data
	Transmitted as a list of pixel color values. 4 bytes per pixel. Pixel color values are processed and determined onboard from the image file. The image is then reconstructed on the ground.
	4108 bytes for small image, 65,548 bytes for medium image, 262,156 bytes for large image

D. **Number of analog channels being used:** None

E. **If analog channels are being used, what are they being used for?**

F. **Number of discrete lines being used:** None

G. **If discrete lines are being used what are they being used for?**
At this time, HELIOS will not use any discrete lines. However, while we are not planning to use any of the discrete commands, we have provided connections from the EDAC connector to a header in case of the event that our discrete command requirements change. If such a thing occurs, then we can implement the necessary logic on an additional board.

H. **Are there any on-board transmitters? If so, list the frequencies being used and the transmitted power.**
No, there are no on-board transmitters

I. **Other relevant downlink telemetry information.**
N/A

IV. Uplink Commanding Specifications:

A. **Command uplink capability required:** [✓ Yes] No (circle one)

B. **If so, will commands be uplinked in regular intervals:** Yes [✓ No] (circle one)

C. **How many commands do you expect to uplink during the flight (can be an absolute number or a rate, i.e. *n commands per hour*)**
The maximum number of commands we expect to uplink is 10 per hour. The average number we expect to uplink is 3 per hour.

D. Provide a table of all of the commands that you will be uplinking to your payload

Most Frequent Commands

Command	Description	Hex	Binary	Flight critical?	Expected Frequency	Verification of execution*	Ramifications if not executed	Contingency plan
Reinitialize	Restart control loop	1	1	N	low	next status packet	less sun visibility	restart system
Switch ADCS method	to photodiode	23	100011	N	low	next status packet	less sun visibility	restart system
	to magnetometer	24	100100	N	low	next status packet	less sun visibility	none
Restart searching algorithm	Retry finding the sun	2A	101010	N	low	next status packet	less sun visibility	restart system
Freeze yaw	Freeze horizontal tracking	33	110011	N	med	next status packet	no night imaging	none
Freeze pitch	Freeze vertical tracking	35	110101	N	low	next status packet	no night imaging	none
Request system health packet	Full system health packet	43	1000011	N	low	next text packet	unknown system status	none
	Small system health packet	44	1000100	Y	low	next status packet	unknown system status	none
Request software health packet	Readings on status of software systems	47	1000111	N	none	next status packet	unknown system status	none

All Commands

Subsystem	Command	Description	Hex	Binary	Flight critical?	Expected Frequency	Verification of execution*	Ramifications if not executed	Contingency plan
ADCS	Reinitialize	Restart control loop	1	1	N	low	NSP**	less sun visibility	restart system
	Uplink pitch	-6 degrees	2	10	N	none	NSP	less sun visibility	none
		-3 degrees	3	11	N	none	NSP	less sun visibility	none
		0 degrees	4	100	N	none	NSP	less sun visibility	none
		3 degrees	5	101	N	none	NSP	less sun visibility	none
		6 degrees	6	110	N	none	NSP	less sun visibility	none
		9 degrees	7	111	N	none	NSP	less sun visibility	none
		12 degrees	8	1000	N	none	NSP	less sun visibility	none

		15 degrees	9	1001	N	none	NSP	less sun visibility	none
		18 degrees	A	1010	N	none	NSP	less sun visibility	none
		21 degrees	B	1011	N	none	NSP	less sun visibility	none
		24 degrees	C	1100	N	none	NSP	less sun visibility	none
		27 degrees	D	1101	N	none	NSP	less sun visibility	none
		30 degrees	E	1110	N	none	NSP	less sun visibility	none
		33 degrees	F	1111	N	none	NSP	less sun visibility	none
		36 degrees	10	10000	N	none	NSP	less sun visibility	none
		39 degrees	11	10001	N	none	NSP	less sun visibility	none
		42 degrees	12	10010	N	none	NSP	less sun visibility	none
		45 degrees	13	10011	N	none	NSP	less sun visibility	none
		48 degrees	14	10100	N	none	NSP	less sun visibility	none
		51 degrees	15	10101	N	none	NSP	less sun visibility	none
		54 degrees	16	10110	N	none	NSP	less sun visibility	none
		57 degrees	17	10111	N	none	NSP	less sun visibility	none
		60 degrees	18	11000	N	none	NSP	less sun visibility	none
		63 degrees	19	11001	N	none	NSP	less sun visibility	none
		66 degrees	1A	11010	N	none	NSP	less sun visibility	none
		69 degrees	1B	11011	N	none	NSP	less sun visibility	none
		72 degrees	1C	11100	N	none	NSP	less sun visibility	none
		75 degrees	1D	11101	N	none	NSP	less sun visibility	none
		78 degrees	1E	11110	N	none	NSP	less sun visibility	none
		81 degrees	1F	11111	N	none	NSP	less sun visibility	none

		84 degrees	20	100000	N	none	NSP	less sun visibility	none
		87 degrees	21	100001	N	none	NSP	less sun visibility	none
		90 degrees	22	100010	N	none	NSP	less sun visibility	none
	Switch ADCS method	To photodiode	23	100011	N	low	NSP	less sun visibility	restart system
		To magneto-meter	24	100100	N	low	NSP	less sun visibility	none
	Request photodiode readings	Extra readings for next data downlink	25	100101	N	none	NSP	unknown status of ADS	none
	Request magnetometer readings	Extra readings for next data downlink	26	100110	N	none	NSP	unknown status of ADS	none
	Request calculated attitude vectors	Past minute	27	100111	N	none	NSP	unknown status of ADS	none
		Past 5 minutes	28	101000	N	none	NSP	unknown status of ADS	none
		Past 20 minutes	29	101001	N	none	NSP	unknown status of ADS	none
	Restart searching algorithm	Retry finding the sun	2A	101010	N	low	NSP	less sun visibility	restart system
	Change step size	Full step - motor 1	2B	101011	N	none	NSP	less motor torque	none
		Half step - motor 1	2C	101100	N	none	NSP	less motor torque	none
		Quarter step - motor 1	2D	101101	N	none	NSP	less accurate sun tracking	restart system
		Eighth step - motor 1	2E	101110	N	none	NSP	less accurate sun tracking	none
		Full step - motor 2	2F	101111	N	none	NSP	less motor torque	none
		Half step - motor 2	30	110000	N	none	NSP	less motor torque	none
		Quarter step - motor 2	31	110001	N	none	NSP	less accurate sun tracking	restart system
		Eighth step - motor 2	32	110010	N	none	NSP	less accurate sun tracking	none
	Freeze yaw	Freeze horizontal tracking	33	110011	N	med	NSP	no night imaging	none

		Unfreeze horizontal tracking	34	110100	N	med	NSP	no day imaging	restart system
	Freeze pitch	Freeze vertical tracking	35	110101	N	low	NSP	no night imaging	none
		Unfreeze vertical tracking	36	110110	N	low	NSP	no day imaging	restart system
SCI	Request image thumbnail	H-alpha camera, small size	37	110111	N	none	NIP***	unknown status of imaging system	none
		H-alpha camera, medium size	38	111000	N	none	NIP	unknown status of imaging system	none
		H-alpha camera, large size	39	111001	N	none	NIP	unknown status of imaging system	none
		CaK camera - small size	3A	111010	N	none	NIP	unknown status of imaging system	none
		Cak camera - medium size	3B	111011	N	none	NIP	unknown status of imaging system	none
		CaK camera - large size	3C	111100	N	none	next image packet	unknown status of imaging system	none
	Change imaging frequency	Change to default frequency sequence	3D	111101	N	none	next status packet	cannot revert to default mission operations without full restart	restart system
		Every 5 seconds	3E	111110	N	none	next status packet	possible lack of space on SSD	none
		Every 10 seconds	3F	111111	N	none	next status packet	possible lack of space on SSD	none
		Every minute	40	1000000	N	none	next status packet	possible lack of space on SSD	none
	Request number of images	Total through flight, in past 5 minutes, frequency changes	41	1000001	Y	low	next status packet	unknown status of imaging sys.	none
	Verify image files can be read	Validates the image file formats	42	1000010	N	med	next status packet	unknown status of imaging sys.	none

System	Request system health packet	Full system health packet	43	1000011	N	low	next text packet	unknown system status	none
		Small system health packet	44	1000100	Y	low	next status packet	unknown system status	none
	Request system time and changes made to clock	Downlink system's current time	45	1000101	N	none	next status packet	unknown system status	none
	Request temper-ature sensor readings	Extra readings for next data downlink	46	1000110	N	none	NSP	unknown system status	none
	Request software health packet	Readings on status of software systems	47	1000111	N	none	NSP	unknown system status	none
	Change highest priority process	Control loop	48	1001000	N	none	NSP	Slow ADS response	restart system
		Imaging	49	1001001	N	none	NSP	Imaging buffers/writes slow entire system	none
	Downlink kernel message buffer	All of flight	4A	1001010	N	low	NTP** **	unknown system status	none
		Past hour	4B	1001011	N	med	NTP	unknown system status	none
	Downlink process queue	All of flight	4C	1001100	N	none	NTP	unknown system status	none
		Past hour	4D	1001101	N	low	NTP	unknown system status	none
	Downlink serial communi-cation types	Uplinked - All of flight	4E	1001110	N	low	NTP	unknown system status	none
		Downlinked - past hour	4F	1001111	N	med	NTP	unknown system status	none

		Downlinked - All of flight	50	1010000	N	low	NTP	unknown system status	none
	Downlink stderr	Past hour	51	1010001	N	med	NTP	unknown system status	none
		All of flight	52	1010010	N	low	NTP	unknown system status	none
	Downlink /var/log/message	All of flight	53	1010011	N	low	NTP	unknown system status	none
		Past hour	54	1010100	N	med	NTP	unknown system status	none
	Downlink /var/log/boot.log	Downlinks the boot process log	55	1010101	N	low	NTP	unknown system status	none
	List corrupt files	Search contents of lost+found	56	1010110	N	low	NTP	unknown system status	none
	Request current process usage	top	57	1010111	N	med	NTP	unknown system status	none
	Disable/ enable individual systems	Imaging off	58	1011000	N	none	NSP	no control if subsystem errors occur	none
		Attitude control off	59	1011001	N	none	NSP	no control if subsystem errors occur	none
		Communication (downlink only) off	5A	1011010	N	none	NSP	no control if subsystem errors occur	none
		Watchdog off	5B	1011011	Y	none	NSP	no control if subsystem errors occur	none
		Imaging on	5C	1011100	N	none	NSP	no control if subsystem errors occur	restart system
		Attitude control on	5D	1011101	N	none	NSP	no control if subsystem errors occur	restart system
		Communication (downlink) on	5E	1011110	N	none	NSP	no control if subsystem errors occur	restart system
		Watchdog on	5F	1011111	N	none	NSP	no control if subsystem errors occur	restart system
	Downlink SSD usage	Condensed directory tree, directory sizes, drive free space	60	1100000	Y	med	NTP	unknown system status	none
	Compress oldest images	1000 images	61	1100001	N	none	NSP	possible lack of space on SSD	none

		2500 images	62	1100010	N	none	NSP	possible lack of space on SSD	none
		All images (until that time)	63	1100011	N	none	NSP	possible lack of space on SSD	none
	Clear downlink buffer	Stops any requested images, packets, etc. from downlinking	63	1100011	N	none	NSP	communication lag	restart system
* Please note that the status packet includes the last received command and a "extra" field for and small requested data bits. Anything listed is in addition to the status packet									
** NSP refers to "Next Status Packet"									
*** NIP refers to "Next Image Packet"									
**** NTP refers to "Next Text Packet"									

E. Are there any on-board receivers? If so, list the frequencies being used.
There are no on-board receivers.

F. Other relevant uplink commanding information.

V. Integration and Logistics

A. Date and Time of your arrival for integration:

We plan to arrive in Palestine, TX the morning of July 30.

B. Approximate amount of time required for integration:
Team HELIOS will be participating in the entire week-long integration schedule. All available time will be used accordingly.

C. Name of the integration team leader: Glenda Alvarenga, Systems Engineer

D. Email address of the integration team leader: Alvarenga.glenda19@gmail.com

E. List ALL integration participants (first and last names) who will be present for integration with their email addresses:

Gabrielle Massone	gabrielle.massone@colorado.edu
Glenda Alvarenga	alvarenga.glenda19@gmail.com
Greg McQuie	greg.mcquie@colorado.edu
Vincent Staverosky	Vincent.staverosky@colorado.edu
Jacob Broadway	Jacob.Broadway@colorado.edu
James Busse	James.Busse@colorado.edu

F. Define a successful integration of your payload:
A successful integration of the HELIOS payload indicates that the payload fully complies with all HASP design constraints in structure (including size and weight), power (drawing no more than 2.5 A at 30 VDC), and communications. The payload

successfully mounts to the supplied PVC mounting plate and to HASP, and connects with the Serial and EDAC communications and power interfaces respectively. Following this, the payload initializes upon "power-up," receives commands and downlinks data packets successfully, and all science and ADCS systems activate.

G. List all expected integration steps:

HELIOS must connect to the serial and EDAC connectors correctly in order to meet the communications and power requirements from HASP. The HELIOS plate must be securely mounted to HASP. Once this has been completed, all the necessary testing (see table below) can be done to complete a successful integration. Testing will culminate in a Thermal/Vacuum test of the entire payload to ensure functionality under flight stressors.

H. List all checks that will determine a successful integration:

Test	Procedure/Equipment	Expected Results
Weight Requirement	Weigh Payload via a Scale	Payload is expected to weigh approximately 13.1 kg
Mounting	Mount payload to CSBF frame	Payload is expected to securely mount to PVC mounting plate and CSBF frame, and the structure experiences no shifting or displacement
Power Requirement	Connect HELIOS to HASP power interface. Measure power drawn from HASP	Payload is expected to successfully interface via EDAC 516 connector and draw ~ 30 VDC at 1.8 – 2.0 A
Uplink Requirement	Connect HELIOS to HASP communications interface. Uplink a command and check HELIOS CPU status to ensure proper command execution.	CPU is expected to receive all uplinked commands and execute properly.
Downlink Requirement	Connect HELIOS to HASP communications interface. Downlink a data package, to ensure data package is received and is packetized format.	Payload is expected to successfully downlink all status, image, and text packets via communications interface.
Communications	Validate proper use of analog channels, test and record transmitter frequency (MHz) to be appropriate, test and record receiver frequency (MHz) to be appropriate,	
Thermal and Vacuum Testing	Place HELIOS in Thermal Vacuum chamber. Take data from CPU and temperature sensors, check for system functionality and failures	
Science Payload Functionality	Test Science and ADCS Functionality indoors with a high intensity light source.	Payload is expected to capture and store images while tracking high intensity light source.

I. List any additional LSU personnel support needed for a successful integration other than directly related to the HASP integration (i.e. lifting, moving equipment, hotel information/arrangements, any special delivery needs…):

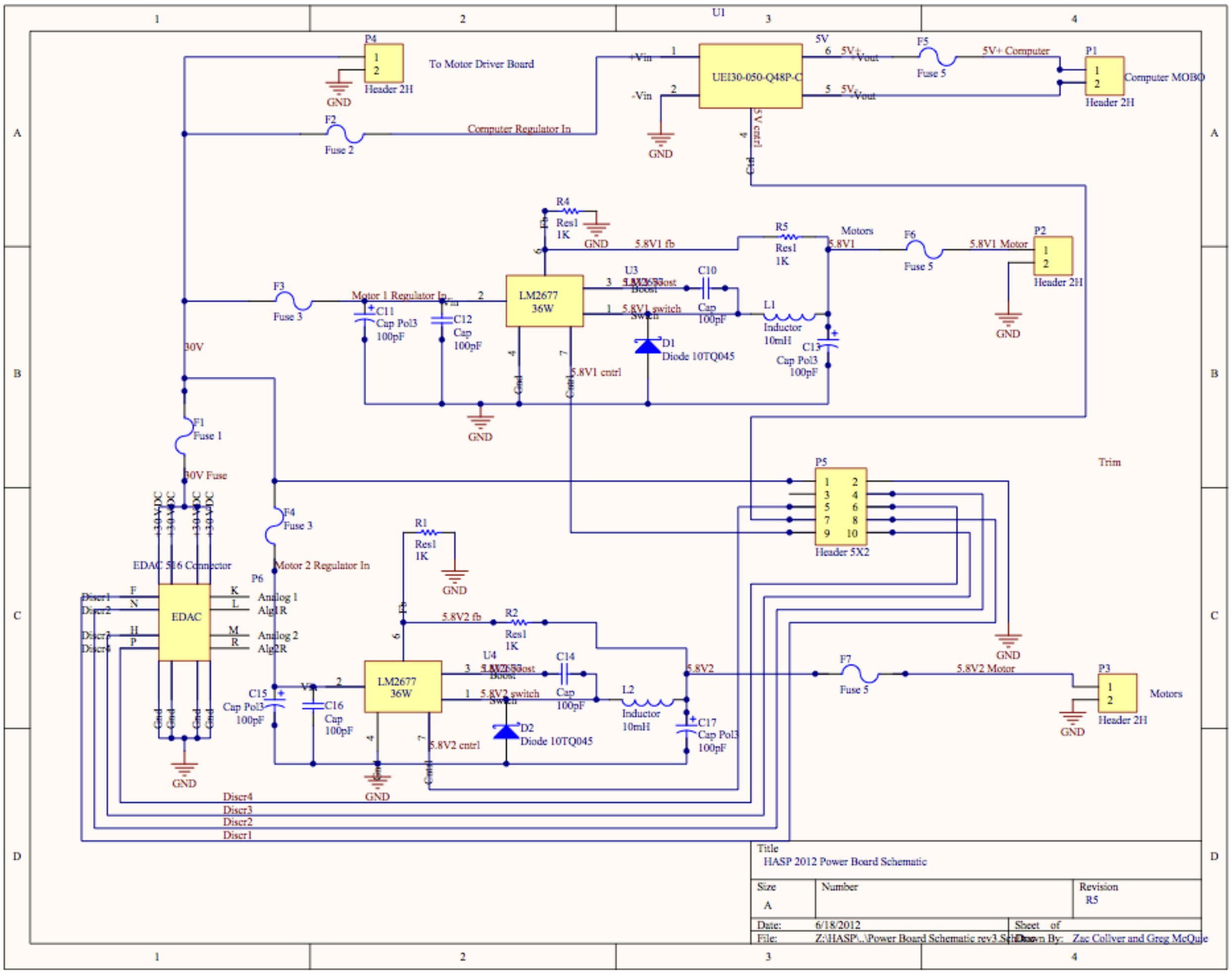
Any additional LSU assistance cannot be forseen at this time. It would be convenient to have block room reservations made at local hotels, but it is not necessary.

J. List any LSU supplied equipment that may be needed for a successful integration: Team HELIOS will require power outlets and an area to work and lay out equipment. All other necessary equipment will be brought with the HELIOS team.

Appendices

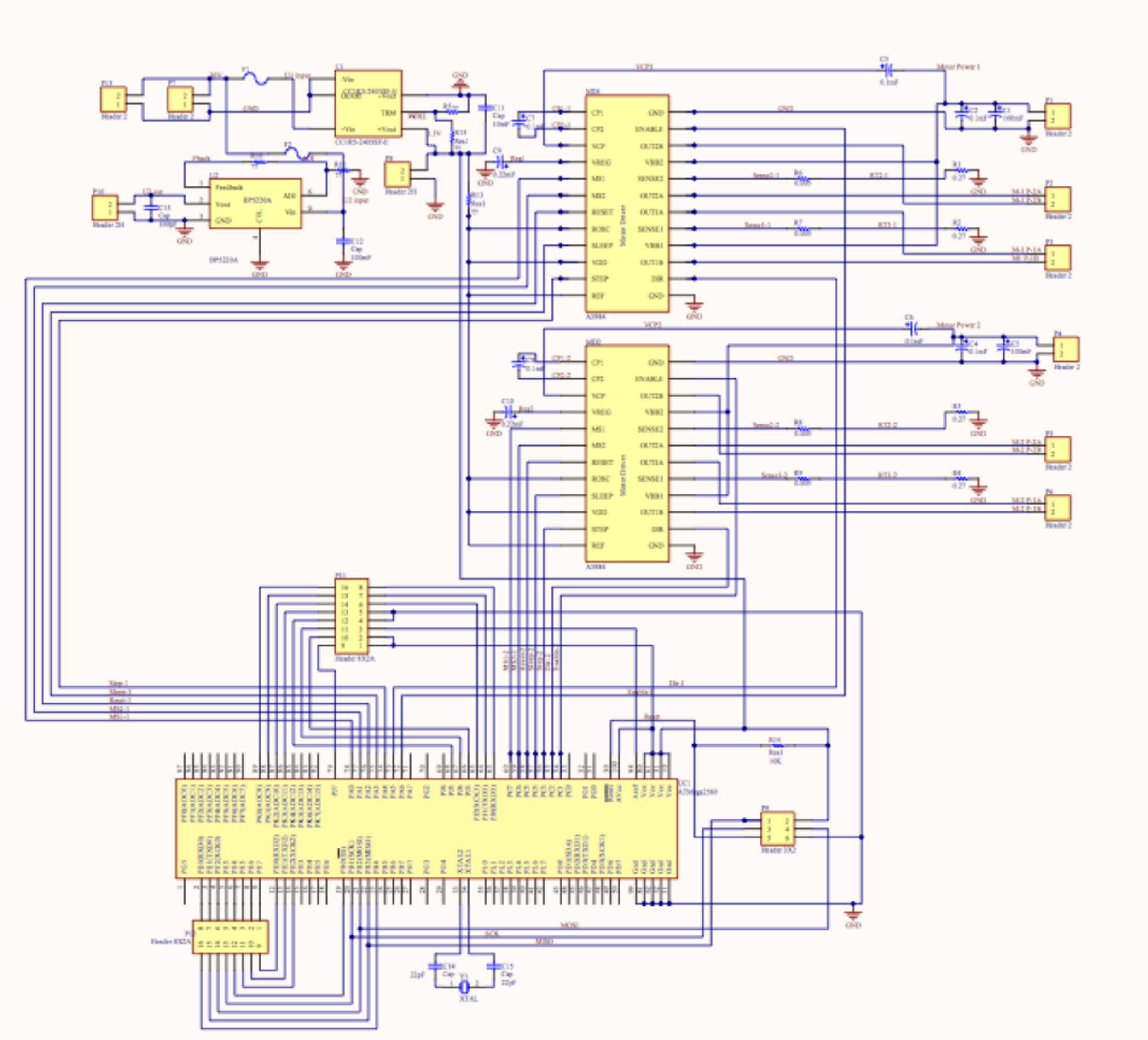
*** Note: All original files have also been attached, as the schematics below lack high resolution for close inspection of components. Also attached is the data sheet for the LM2677 voltage regulator.*

Power Board Schematic



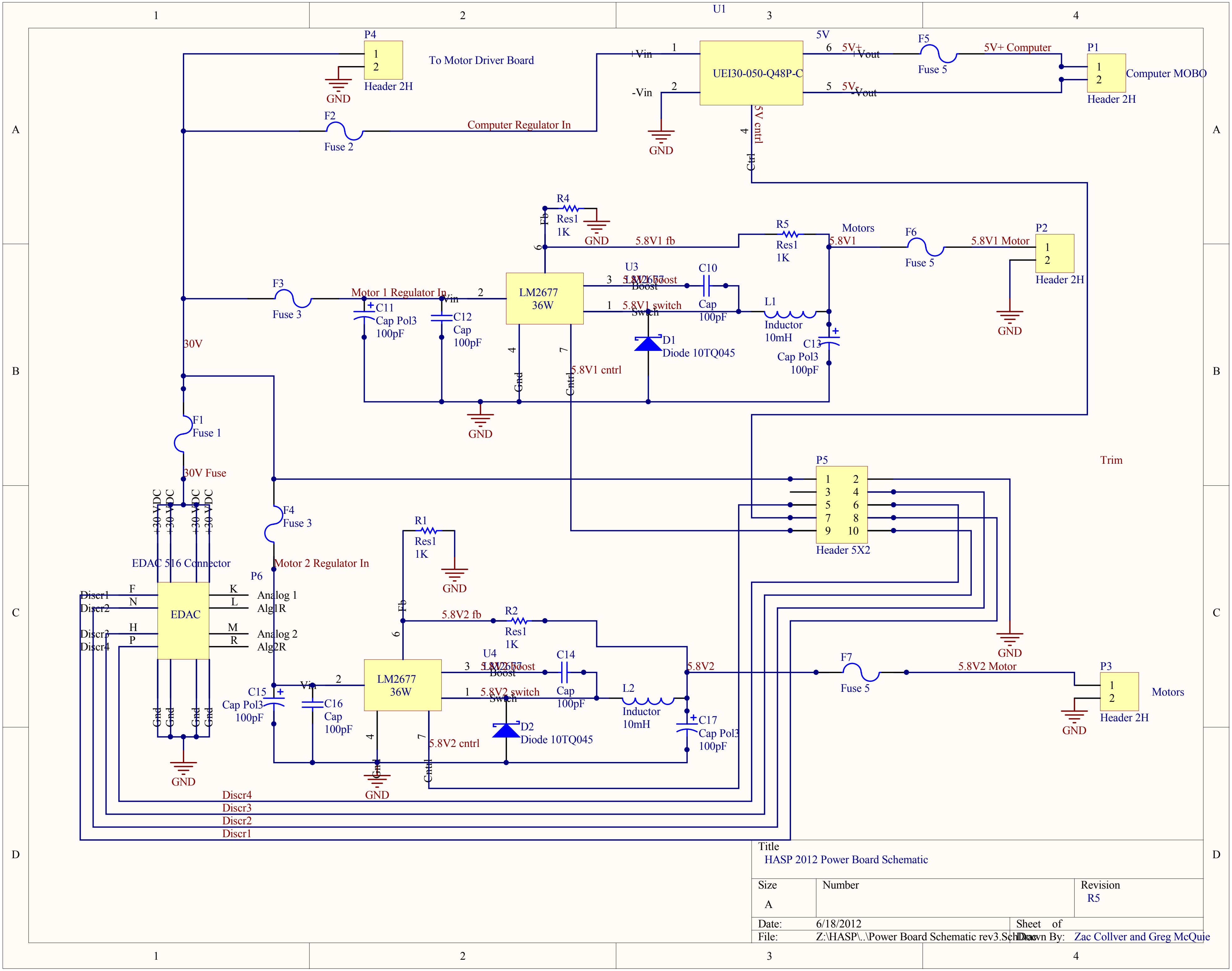
e	System	Description
6/17	Software / ADCS	Motor Driver code (semi-functional)

Motor Board



Schedule

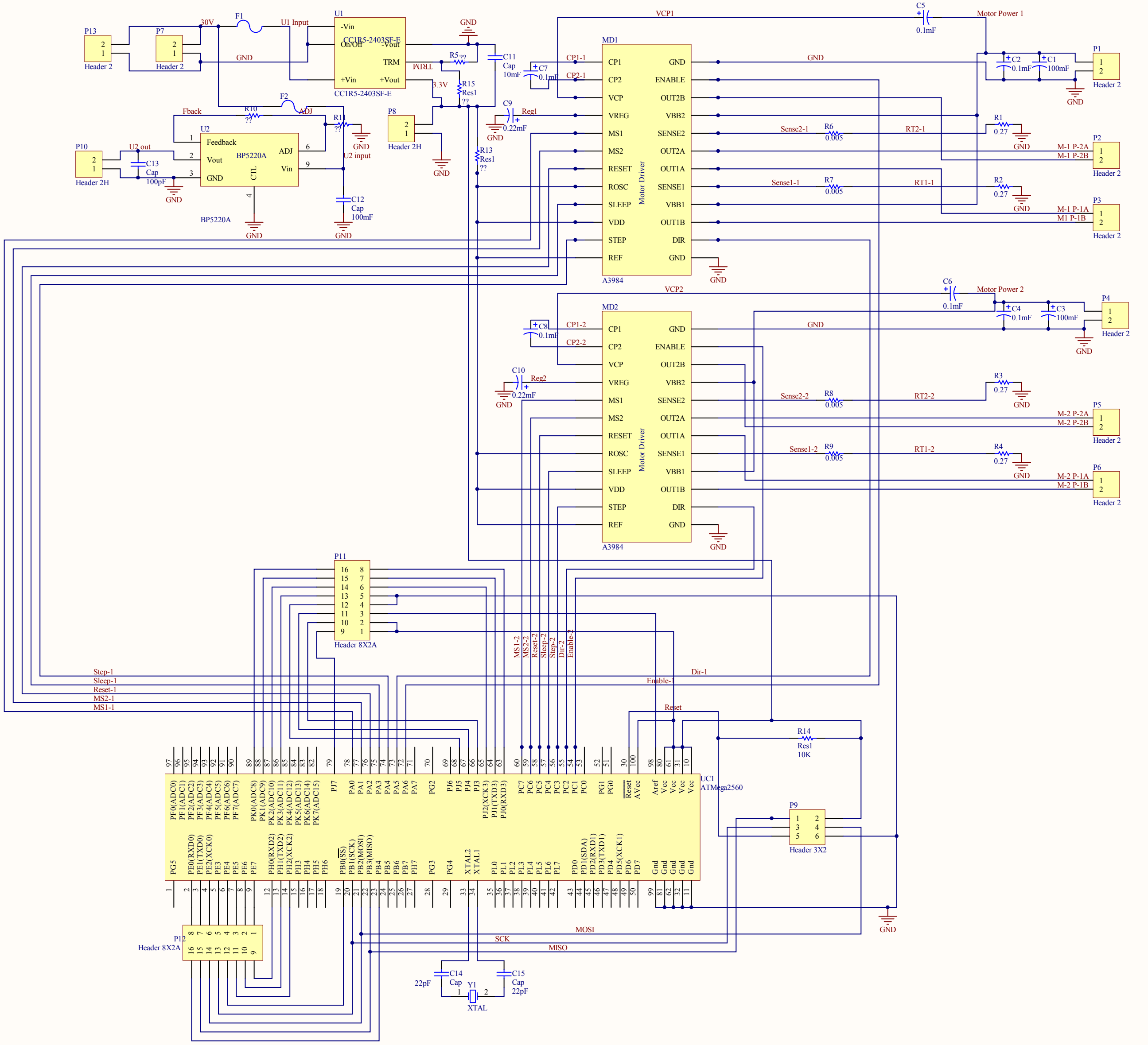
6/20	All	All components ordered and awaiting assembly/testing
6/20	All	Critical Design Review at Space Grant
6/21	Structure	All structure widths and lengths complete
6/28	ADCS	Pitch Arms Machined
6/29	Software	Serial Communication code Functional
6/30	Software / ADCS	Basic ADCS Code functional
7/1	Software / ADCS	Microcontroller communication code complete
7/3	Structure	Structure complete and assembled
7/3	ADCS	Chain Drive Assembled
7/8	Software	Reading all sensors
7/9	ADCS/ Software	Complete integration of ADCS mechanical system and photodiode configuration
7/9	Science/ Software	Science system calibration complete (Collimating Light Testing @ CASA complete), camera communication tested
7/9	Science/ Software	Science system calibration complete (Calumniating light testing @ CASA complete), camera communication tested
7/11	Power / Software	All PCB assembly complete
7/11	All	Complete integrated payload
7/12 -7/13	All	Thermal and Vacuum testing @ CASA
7/12 - 7/16	All	"Day in the life" testing
7/16	All	System Failure Analysis
7/17	Software / ADCS	Control Loop code complete
7/18	Software	All electrical System test complete
7/18	Software	All computing Hardware tests complete
7/26	All	All system/payload correction complete/imaging code complete
7/30– 8/3	All	Student Payload integration w/HASP& T/V testing @ Palestine, TX. All manufacturing absolutely complete.
8/4 - 8/26	All	Minor payload modifications based on Integration Results
8/27 – 8/31	All	Flight Operations, final check out, hang test, FRR @ Ft. Sumner, NM
9/3	All	Launch!



Title
HASP 2012 Power Board Schematic

Size	Number	Revision
A		R5

Date: 6/18/2012
Sheet of
File: Z:\HASP\..\Power Board Schematic rev3.SchDoc
Drawn By: Zac Collver and Greg McQuie



Title
Motor Board.SchDoc

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Revision
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Drawn By: Zac Collver and Greg McQuie

LM2677

LM2677 SIMPLE SWITCHER High Efficiency 5A Step-Down Voltage Regulator with Sync

Literature Number: SNVS077H

National Semiconductor

February 21, 2008

LM2677
SIMPLE SWITCHER® High Efficiency 5A Step-Down Voltage Regulator with Sync

General Description

The LM2677 series of regulators are monolithic integrated circuits which provide all of the active functions for a step-down (buck) switching regulator capable of driving up to 5A loads with excellent line and load regulation characteristics. High efficiency (>90%) is obtained through the use of a low ON-resistance DMOS power switch. The series consists of fixed output voltages of 3.3V, 5V and 12V and an adjustable output version.

The SIMPLE SWITCHER concept provides for a complete design using a minimum number of external components. The switching clock frequency can be provided by an internal fixed frequency oscillator (260KHz) or from an externally provided clock in the range of 280KHz to 400Khz which allows the use of physically smaller sized components. A family of standard inductors for use with the LM2677 are available from several manufacturers to greatly simplify the design process. The external Sync clock provides direct and precise control of the output ripple frequency for consistent filtering or frequency spectrum positioning.

The LM2677 series also has built in thermal shutdown, current limiting and an ON/OFF control input that can power down the regulator to a low 50μA quiescent current standby condition. The output voltage is guaranteed to a ±2% tolerance.

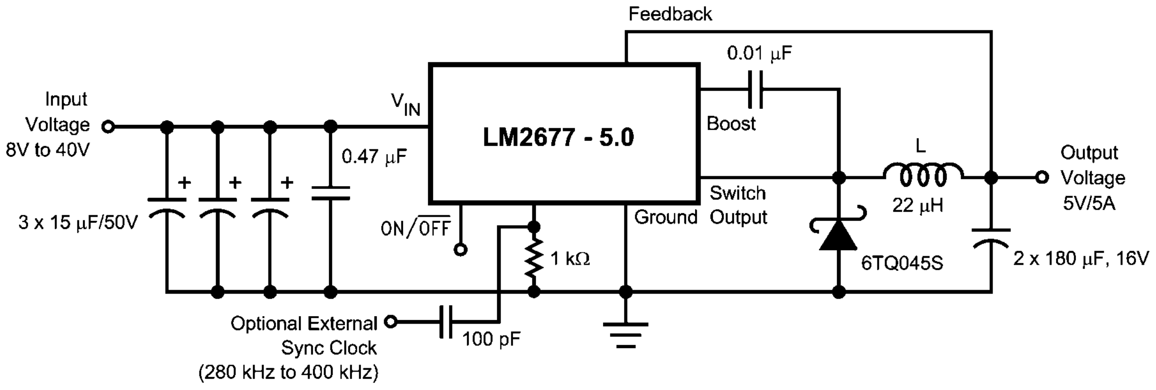
Features

- Efficiency up to 92%
- Simple and easy to design with (using off-the-shelf external components)
- 100 mΩ DMOS output switch
- 3.3V, 5V and 12V fixed output and adjustable (1.2V to 37V) versions
- 50μA standby current when switched OFF
- ±2%maximum output tolerance over full line and load conditions
- Wide input voltage range: 8V to 40V
- External Sync clock capability (280KHz to 400KHz)
- 260 KHz fixed frequency internal oscillator
- −40 to +125°C operating junction temperature range

Applications

- Simple to design, high efficiency (>90%) step-down switching regulators
- Efficient system pre-regulator for linear voltage regulators
- Battery chargers
- Communications and radio equipment regulator with synchronized clock frequency

Typical Application



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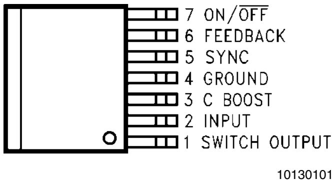
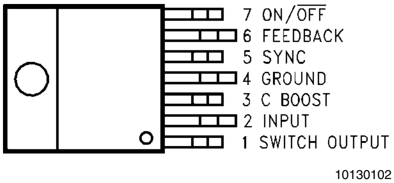
Connection Diagrams and Ordering Information

TO-263 Package
Top View



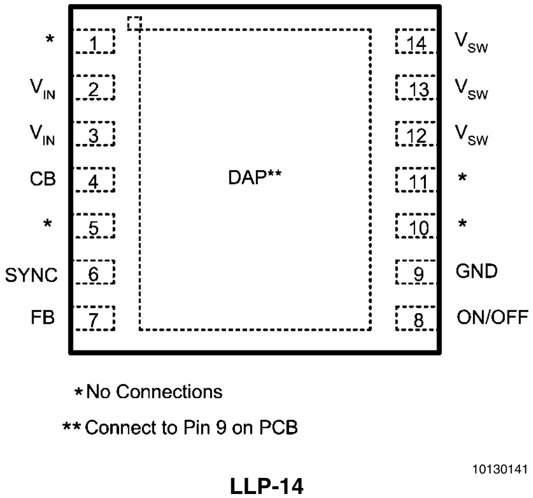
Order Number
LM2677S-3.3, LM2677S-5.0,
LM2677S-12 or LM2677S-ADJ
See NSC Package Number TS7B

TO-220 Package
Top View



Order Number
LM2677T-3.3, LM2677T-5.0,
LM2677T-12 or LM2677T-ADJ
See NSC Package Number TA07B

Top View



LLP-14
See NS package Number SRC14A

Ordering Information for LLP Package

Output Voltage	Order Information	Package Marking	Supplied As
12	LM2677SD-12	S0002XB	250 Units on Tape and Reel
12	LM2677SDX-12	S0002XB	2500 Units on Tape and Reel
3.3	LM2677SD-3.3	S0002YB	250 Units on Tape and Reel
3.3	LM2677SDX-3.3	S0002YB	2500 Units on Tape and Reel
5.0	LM2677SD-5.0	S0002ZB	250 Units on Tape and Reel
5.0	LM2677SDX-5.0	S0002ZB	2500 Units on Tape and Reel
ADJ	LM2677SD-ADJ	S0003AB	250 Units on Tape and Reel
ADJ	LM2677SDX-ADJ	S0003AB	2500 Units on Tape and Reel

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Input Supply Voltage	45V
ON/OFF Pin Voltage	−0.1V to 6V
Switch Voltage to Ground (Note 12)	−1V to V_{IN}
Boost Pin Voltage	V_{SW} + 8V
Feedback Pin Voltage	−0.3V to 14V
Power Dissipation	Internally Limited
ESD (Note 2)	2 kV
Storage Temperature Range	−65°C to 150°C
Soldering Temperature	
Wave	4 sec, 260°C
Infrared	10 sec, 240°C
Vapor Phase	75 sec, 219°C

Operating Ratings

Supply Voltage	8V to 40V
Junction Temperature Range (T_J)	−40°C to 125°C

Electrical Characteristics

Limits appearing in **bold type face** apply over the entire junction temperature range of operation, −40°C to 125°C. Specifications appearing in normal type apply for $T_A = T_J = 25°C$. Sync pin open circuited.

LM2677-3.3

Symbol	Parameter	Conditions	Typical (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{OUT}	Output Voltage	V_{IN} = 8V to 40V, 100mA ≤ I_{OUT} ≤ 5A	3.3	3.234/**3.201**	3.366/**3.399**	V
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 5A	82			%

LM2677-5.0

Symbol	Parameter	Conditions	Typical (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{OUT}	Output Voltage	V_{IN} = 8V to 40V, 100mA ≤ I_{OUT} ≤ 5A	5.0	4.900/**4.850**	5.100/**5.150**	V
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 5A	84			%

LM2677-12

Symbol	Parameter	Conditions	Typical (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{OUT}	Output Voltage	V_{IN} = 15V to 40V, 100mA ≤ I_{OUT} ≤ 5A	12	11.76/**11.64**	12.24/**12.36**	V
η	Efficiency	V_{IN} = 24V, I_{LOAD} = 5A	92			%

LM2677-ADJ

Symbol	Parameter	Conditions	Typ (Note 3)	Min (Note 4)	Max (Note 4)	Units
V_{FB}	Feedback Voltage	V_{IN} = 8V to 40V, 100mA ≤ I_{OUT} ≤ 5A V_{OUT} Programmed for 5V	1.21	1.186/**1.174**	1.234/**1.246**	V
η	Efficiency	V_{IN} = 12V, I_{LOAD} = 5A	84			%

All Output Voltage Versions Electrical Characteristics

Limits appearing in **bold type face** apply over the entire junction temperature range of operation, −40°C to 125°C.

Specifications appearing in normal type apply for $T_A = T_J = 25°C$. Unless otherwise specified V_{IN}=12V for the 3.3V, 5V and Adjustable versions and V_{IN}=24V for the 12V version, Sync pin open circuited..

Symbol	Parameter	Conditions	Typ	Min	Max	Units
DEVICE PARAMETERS						
I_Q	Quiescent Current	$V_{FEEDBACK}$ = 8V For 3.3V, 5.0V, and ADJ Versions $V_{FEEDBACK}$ = 15V For 12V Versions	4.2		6	mA
I_{STBY}	Standby Quiescent Current	ON/OFF Pin = 0V	50		100/**150**	μA
I_{CL}	Current Limit		7	6.1/**5.75**	8.3/**8.75**	A
I_L	Output Leakage Current	V_{IN} = 40V, ON/OFF Pin = 0V V_{SWITCH} = 0V	1		200 15	μA
		V_{SWITCH} = −1V	6			mA
$R_{DS(ON)}$	Switch On-Resistance	I_{SWITCH} = 5A	0.12		0.14/**0.225**	Ω
f_O	Oscillator Frequency	Measured at Switch Pin	260	**225**	**280**	kHz
D	Duty Cycle	Maximum Duty Cycle Minimum Duty Cycle	91 0			% %
I_{BIAS}	Feedback Bias Current	$V_{FEEDBACK}$ = 1.3V ADJ Version Only	85			nA
$V_{ON/OFF}$	ON/OFF Threshold Voltage		1.4	**0.8**	**2.0**	V
$I_{ON/OFF}$	ON/OFF Input Current	ON/OFF Input = 0V	20		**45**	μA
F_{SYNC}	Synchronization Frequency	V_{SYNC}(Pin 5)=3.5V, 50% Duty Cycle	400			KHz
V_{SYNC}	SYNC Threshold Voltage		1.4			V
θ_{JA}	Thermal Resistance	T Package, Junction to Ambient (Note 5)	65			°C/W
θ_{JA}		T Package, Junction to Ambient (Note 6)	45			
θ_{JC}		T Package, Junction to Case	2			
θ_{JA}		S Package, Junction to Ambient (Note 7)	56			
θ_{JA}		S Package, Junction to Ambient (Note 8)	35			
θ_{JA}		S Package, Junction to Ambient (Note 9)	26			
θ_{JC}		S Package, Junction to Case	2			++
θ_{JA}		SD Package, Junction to Ambient (Note 10)	55			°C/W
θ_{JA}		SD Package, Junction to Ambient (Note 11)	29			

Note 1: Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings indicate conditions under which of the device is guaranteed. Operating Ratings do not imply guaranteed performance limits. For guaranteed performance limits and associated test condition, see the electrical Characteristics tables.

Note 2: ESD was applied using the human-body model, a 100pF capacitor discharged through a 1.5 kΩ resistor into each pin.

Note 3: Typical values are determined with $T_A = T_J = 25°C$ and represent the most likely norm.

Note 4: All limits are guaranteed at room temperature (standard type face) and at **temperature extremes (bold type face)**. All room temperature limits are 100% tested during production with $T_A = T_J = 25°C$. All limits at temperature extremes are guaranteed via correlation using standard standard Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

Note 5: Junction to ambient thermal resistance (no external heat sink) for the 7 lead TO-220 package mounted vertically, with ½ inch leads in a socket, or on a PC board with minimum copper area.

Note 6: Junction to ambient thermal resistance (no external heat sink) for the 7 lead TO-220 package mounted vertically, with ½ inch leads soldered to a PC board containing approximately 4 square inches of (1 oz.) copper area surrounding the leads.

Note 7: Junction to ambient thermal resistance for the 7 lead TO-263 mounted horizontally against a PC board area of 0.136 square inches (the same size as the TO-263 package) of 1 oz. (0.0014 in. thick) copper.

Note 8: Junction to ambient thermal resistance for the 7 lead TO-263 mounted horizontally against a PC board area of 0.4896 square inches (3.6 times the area of the TO-263 package) of 1 oz. (0.0014 in. thick) copper.

Note 9: Junction to ambient thermal resistance for the 7 lead TO-263 mounted horizontally against a PC board copper area of 1.0064 square inches (7.4 times the area of the TO-263 package) of 1 oz. (0.0014 in. thick) copper. Additional copper area will reduce thermal resistance further. See the thermal model in Switchers Made Simple® software.

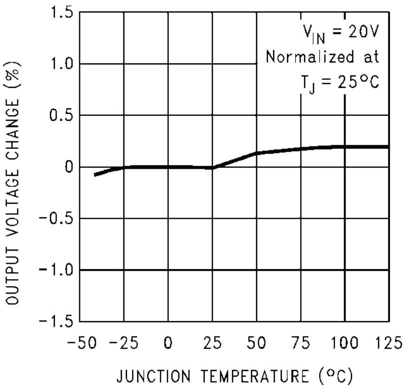
Note 10: Junction to ambient thermal resistance for the 14-lead LLP mounted on a PC board copper area equal to the die attach paddle.

Note 11: Junction to ambient thermal resistance for the 14-lead LLP mounted on a PC board copper area using 12 vias to a second layer of copper equal to die attach paddle. Additional copper area will reduce thermal resistance further. For layout recommendations, refer to Application Note AN-1187.

Note 12: The absolute maximum specification of the 'Switch Voltage to Ground' applies to DC voltage. An extended negative voltage limit of -10V applies to a pulse of up to 20 ns, -6V of 60 ns and -3V of up to 100 ns.

Typical Performance Characteristics

Normalized Output Voltage



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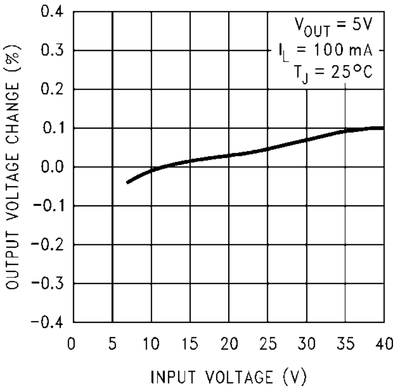
Line Regulation



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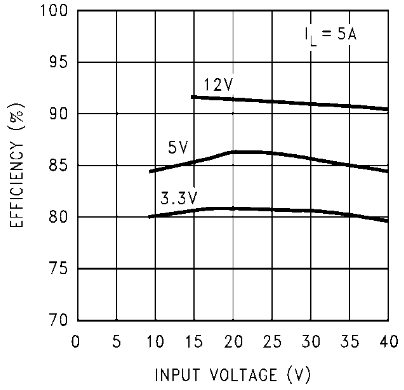
Efficiency vs Input Voltage



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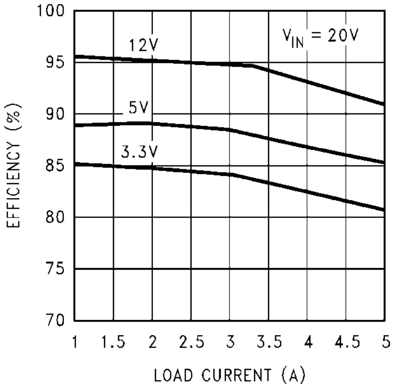
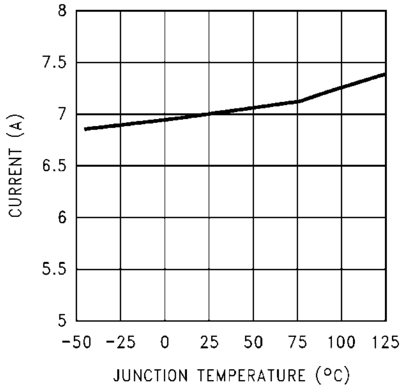
Efficiency vs I_{LOAD}



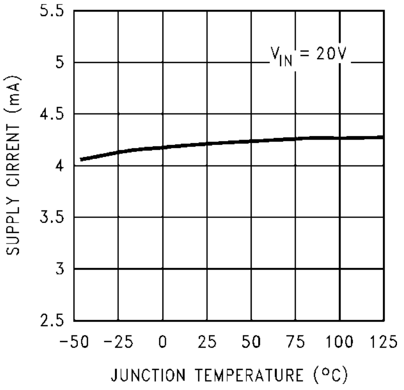
10130112

Switch Current Limit



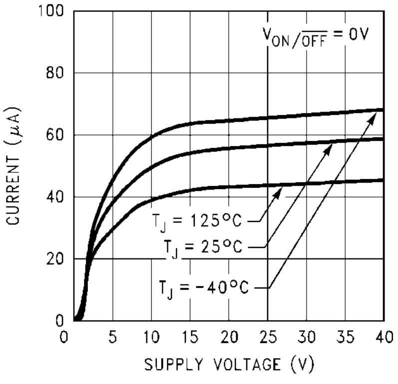
10130104

Operating Quiescent Current



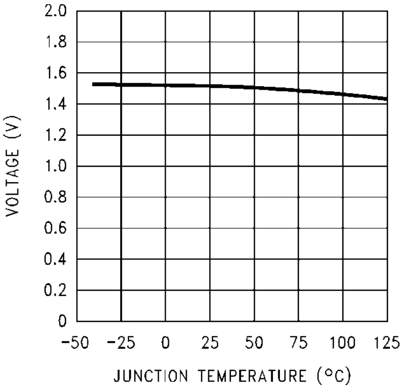
10130105

Standby Quiescent Current



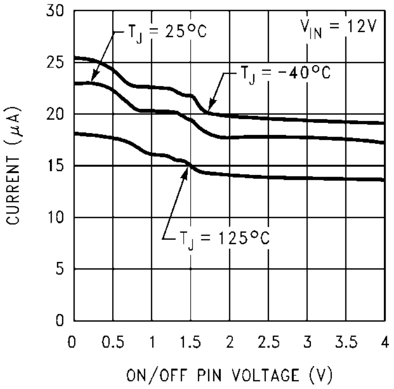
10130140

ON/OFF Threshold Voltage



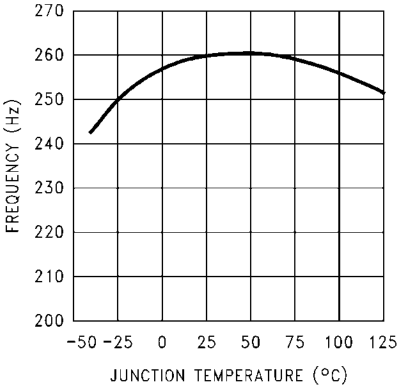
10130113

ON/OFF Pin Current (Sourcing)



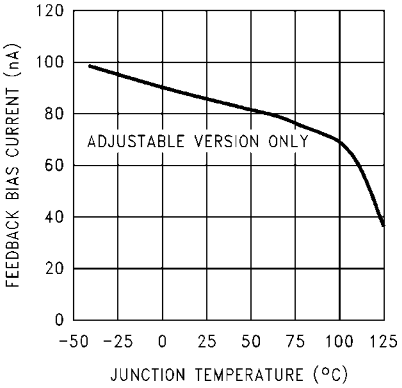
10130114

Switching Frequency



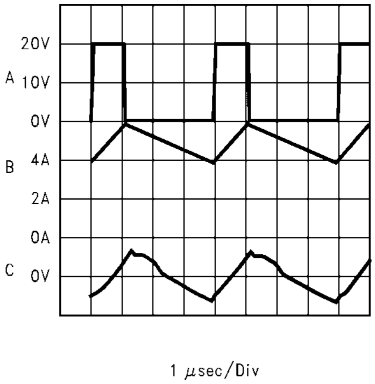
10130115

Feedback Pin Bias Current



10130116

Continuous Mode Switching Waveforms V_{IN} = 20V, V_{OUT} = 5V, I_{LOAD} = 5A L = 10 µH, C_{OUT} = 400 µF, C_{OUT}ESR = 13 mΩ



10130117

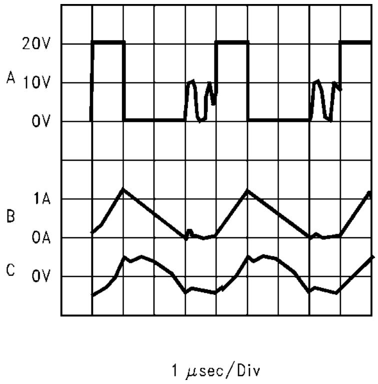
A: V_{SW} Pin Voltage, 10 V/div.

B: Inductor Current, 2 A/div

C: Output Ripple Voltage, 20 mV/div AC-Coupled

Horizontal Time Base: 1 µs/div

Discontinuous Mode Switching Waveforms V_{IN} = 20V, V_{OUT} = 5V, I_{LOAD} = 500 mA L = 10 µH, C_{OUT} = 400 µF, C_{OUT}ESR = 13 mΩ



10130118

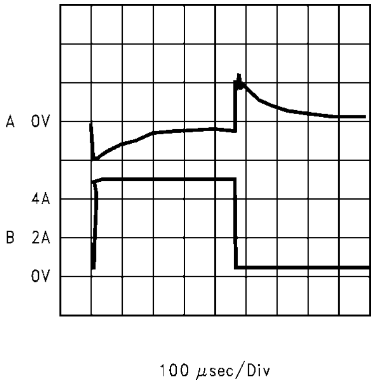
A: V_{SW} Pin Voltage, 10 V/div.

B: Inductor Current, 1 A/div

C: Output Ripple Voltage, 20 mV/div AC-Coupled

Horizontal Time Base: 1 µs//iv

Load Transient Response for Continuous Mode V_{IN} = 20V, V_{OUT} = 5V L = 10 µH, C_{OUT} = 400 µF, C_{OUT}ESR = 13 mΩ



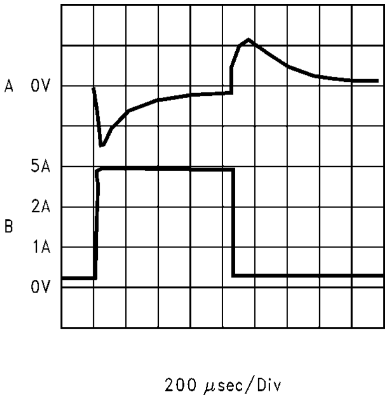
10130119

A: Output Voltage, 100 mV//div, AC-Coupled.

B: Load Current: 500 mA to 5A Load Pulse

Horizontal Time Base: 100 µs/div

Load Transient Response for Discontinuous Mode V_{IN} = 20V, V_{OUT} = 5V, L = 10 µH, C_{OUT} = 400 µF, C_{OUT}ESR = 13 mΩ



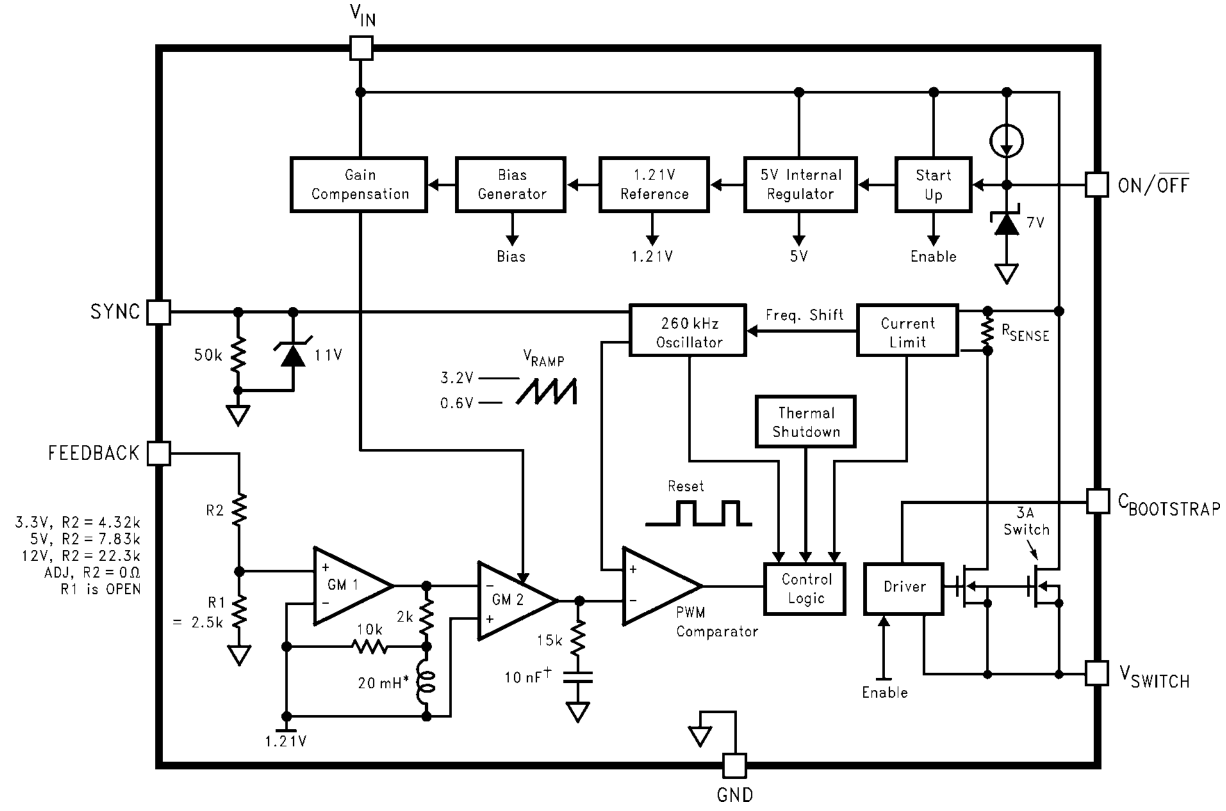
10130120

A: Output Voltage, 100 mV/div, AC-Coupled.

B: Load Current: 200 mA to 5A Load Pulse

Horizontal Time Base: 200 µs/div

Block Diagram



10130106

* Active Inductor Patent Number 5,514,947

† Active Capacitor Patent Number 5,382,918

Application Hints

The LM2677 provides all of the active functions required for a step-down (buck) switching regulator. The internal power switch is a DMOS power MOSFET to provide power supply designs with high current capability, up to 5A, and highly efficient operation.

The LM2677 is part of the SIMPLE SWITCHER family of power converters. A complete design uses a minimum number of external components, which have been pre-determined from a variety of manufacturers. Using either this data sheet or a design software program called ***Switchers Made Simple*** a complete switching power supply can be designed quickly. The software is provided free of charge and can be downloaded from National Semiconductor's Internet site located at http://www.national.com.

SWITCH OUTPUT

This is the output of a power MOSFET switch connected directly to the input voltage. The switch provides energy to an inductor, an output capacitor and the load circuitry under control of an internal pulse-width-modulator (PWM). The PWM controller is internally clocked by a fixed 260KHz oscillator. In a standard step-down application the duty cycle (Time ON/ Time OFF) of the power switch is proportional to the ratio of the power supply output voltage to the input voltage. The voltage on pin 1 switches between Vin (switch ON) and below ground by the voltage drop of the external Schottky diode (switch OFF).

INPUT

The input voltage for the power supply is connected to pin 2. In addition to providing energy to the load the input voltage also provides bias for the internal circuitry of the LM2677. For guaranteed performance the input voltage must be in the range of 8V to 40V. For best performance of the power supply the input pin should always be bypassed with an input capacitor located close to pin 2.

C BOOST

A capacitor must be connected from pin 3 to the switch output, pin 1. This capacitor boosts the gate drive to the internal MOSFET above Vin to fully turn it ON. This minimizes conduction losses in the power switch to maintain high efficiency. The recommended value for C Boost is 0.01µF.

GROUND

This is the ground reference connection for all components in the power supply. In fast-switching, high-current applications such as those implemented with the LM2677, it is recommended that a broad ground plane be used to minimize signal coupling throughout the circuit

SYNC

This input allows control of the switching clock frequency. If left open-circuited the regulator will be switched at the internal oscillator frequency, between 225KHz and 280KHz. An external clock can be used to force the switching frequency and thereby control the output ripple frequency of the regulator. This capability provides for consistent filtering of the output ripple from system to system as well as precise frequency spectrum positioning of the ripple frequency which is often desired in communications and radio applications. This external frequency must be greater than the LM2677 internal oscillator frequency, which could be as high as 280KHz, to prevent an erroneous reset of the internal ramp oscillator and PWM control of the power switch. The ramp oscillator is reset on the positive going edge of the sync input signal. It is recommended that the external TTL or CMOS compatible clock (between 0V and a level greater than 3V) be ac coupled to the sync input through a 100pf capacitor and a 1KΩ resistor to ground at pin 5 as shown in*Figure 1*.

FEEDBACK

This is the input to a two-stage high gain amplifier, which drives the PWM controller. It is necessary to connect pin 6 to the actual output of the power supply to set the dc output voltage. For the fixed output devices (3.3V, 5V and 12V outputs), a direct wire connection to the output is all that is required as internal gain setting resistors are provided inside the LM2677. For the adjustable output version two external resistors are required to set the dc output voltage. For stable operation of the power supply it is important to prevent coupling of any inductor flux to the feedback input.

ON/OFF

This input provides an electrical ON/OFF control of the power supply. Connecting this pin to ground or to any voltage less than 0.8V will completely turn OFF the regulator. The current drain from the input supply when OFF is only 50µA. Pin 7 has an internal pull-up current source of approximately 20µA and a protection clamp zener diode of 7V to ground. When electrically driving the ON/OFF pin the high voltage level for the ON condition should not exceed the 6V absolute maximum limit. When ON/OFF control is not required pin 7 should be left open circuited.

DAP (LLP PACKAGE)

The Die Attach Pad (DAP) can and should be connected to PCB Ground plane/island. For CAD and assembly guidelines refer to Application Note AN-1187 at http://power.national.com.

DESIGN CONSIDERATIONS

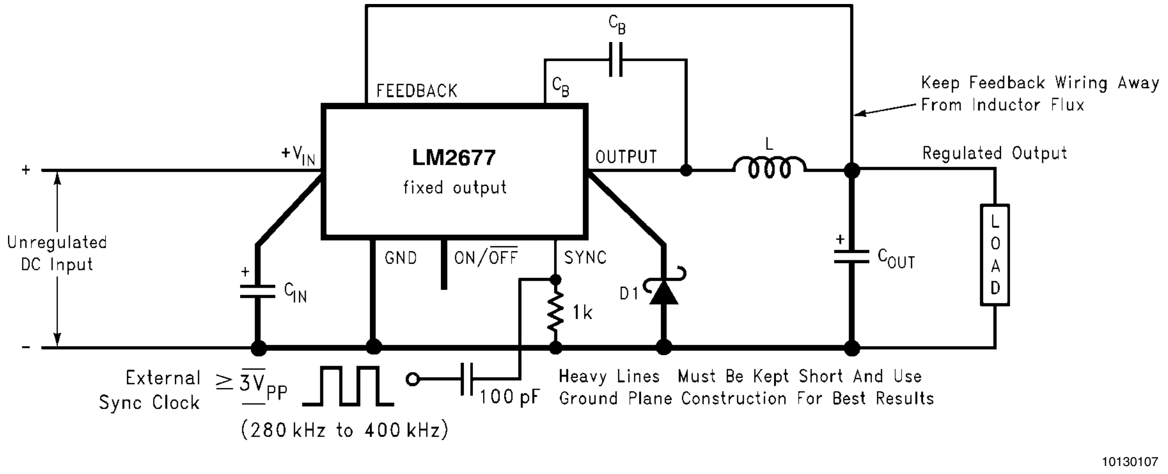


FIGURE 1. Basic circuit for fixed output voltage applications.

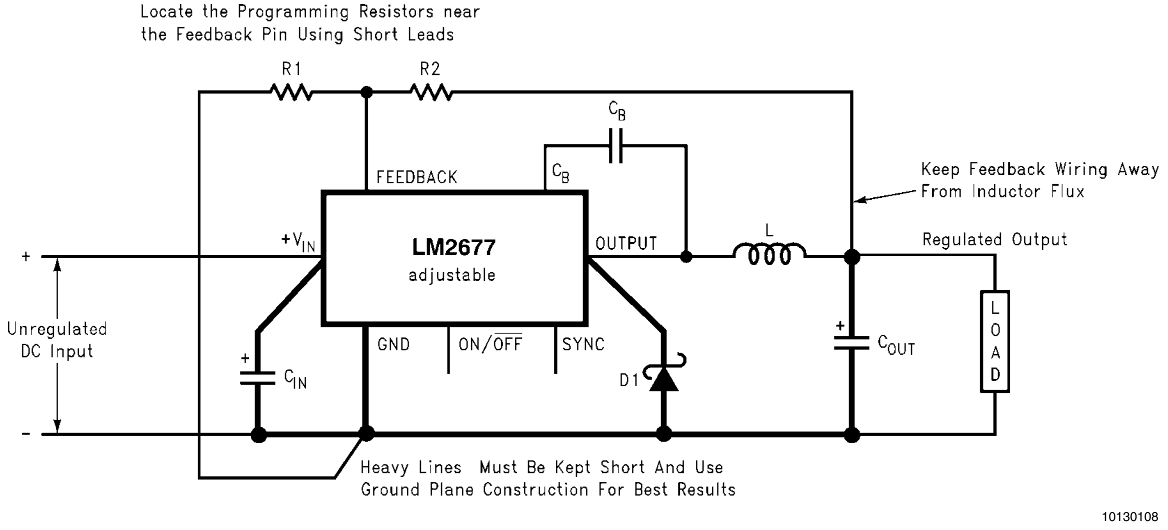


FIGURE 2. Basic circuit for adjustable output voltage applications

Power supply design using the LM2677 is greatly simplified by using recommended external components. A wide range of inductors, capacitors and Schottky diodes from several manufacturers have been evaluated for use in designs that cover the full range of capabilities (input voltage, output voltage and load current) of the LM2677. A simple design procedure using nomographs and component tables provided in this data sheet leads to a working design with very little effort. Alternatively, the design software, ***LM267X Made Simple*** (version 6.0), can also be used to provide instant component selection, circuit performance calculations for evaluation, a bill of materials component list and a circuit schematic.

The individual components from the various manufacturers called out for use are still just a small sample of the vast array of components available in the industry. While these components are recommended, they are not exclusively the only components for use in a design. After a close comparison of component specifications, equivalent devices from other manufacturers could be substituted for use in an application.

Important considerations for each external component and an explanation of how the nomographs and selection tables were developed follows.

INDUCTOR

The inductor is the key component in a switching regulator. For efficiency the inductor stores energy during the switch ON time and then transfers energy to the load while the switch is OFF.

Nomographs are used to select the inductance value required for a given set of operating conditions. The nomographs assume that the circuit is operating in continuous mode (the current flowing through the inductor never falls to zero). The magnitude of inductance is selected to maintain a maximum ripple current of 30% of the maximum load current. If the ripple current exceeds this 30% limit the next larger value is selected.

The inductors offered have been specifically manufactured to provide proper operation under all operating conditions of input and output voltage and load current. Several part types are offered for a given amount of inductance. Both surface mount and through-hole devices are available. The inductors from each of the three manufacturers have unique characteristics.

Renco: ferrite stick core inductors; benefits are typically lowest cost and can withstand ripple and transient peak currents above the rated value. These inductors have an external magnetic field, which may generate EMI.

Pulse Engineering: powdered iron toroid core inductors; these also can withstand higher than rated currents and, being toroid inductors, will have low EMI.

Coilcraft: ferrite drum core inductors; these are the smallest physical size inductors and are available only as surface mount components. These inductors also generate EMI but less than stick inductors.

OUTPUT CAPACITOR

The output capacitor acts to smooth the dc output voltage and also provides energy storage. Selection of an output capacitor, with an associated equivalent series resistance (ESR), impacts both the amount of output ripple voltage and stability of the control loop.

The output ripple voltage of the power supply is the product of the capacitor ESR and the inductor ripple current. The capacitor types recommended in the tables were selected for having low ESR ratings.

In addition, both surface mount tantalum capacitors and through-hole aluminum electrolytic capacitors are offered as solutions.

Impacting frequency stability of the overall control loop, the output capacitance, in conjunction with the inductor, creates a double pole inside the feedback loop. In addition the capacitance and the ESR value create a zero. These frequency response effects together with the internal frequency compensation circuitry of the LM2677 modify the gain and phase shift of the closed loop system.

As a general rule for stable switching regulator circuits it is desired to have the unity gain bandwidth of the circuit to be limited to no more than one-sixth of the controller switching frequency. With the fixed 260KHz switching frequency of the LM2677, the output capacitor is selected to provide a unity gain bandwidth of 40KHz maximum. Each recommended capacitor value has been chosen to achieve this result.

In some cases multiple capacitors are required either to reduce the ESR of the output capacitor, to minimize output ripple (a ripple voltage of 1% of Vout or less is the assumed performance condition), or to increase the output capacitance to reduce the closed loop unity gain bandwidth (to less than 40KHz). When parallel combinations of capacitors are required it has been assumed that each capacitor is the exact same part type.

The RMS current and working voltage (WV) ratings of the output capacitor are also important considerations. In a typical step-down switching regulator, the inductor ripple current (set to be no more than 30% of the maximum load current by the inductor selection) is the current that flows through the output capacitor. The capacitor RMS current rating must be greater than this ripple current. The voltage rating of the output capacitor should be greater than 1.3 times the maximum output voltage of the power supply. If operation of the system at elevated temperatures is required, the capacitor voltage rating may be de-rated to less than the nominal room temperature rating. Careful inspection of the manufacturer's specification for de-rating of working voltage with temperature is important.

INPUT CAPACITOR

Fast changing currents in high current switching regulators place a significant dynamic load on the unregulated power source. An input capacitor helps to provide additional current to the power supply as well as smooth out input voltage variations.

Like the output capacitor, the key specifications for the input capacitor are RMS current rating and working voltage. The RMS current flowing through the input capacitor is equal to one-half of the maximum dc load current so the capacitor should be rated to handle this. Paralleling multiple capacitors proportionally increases the current rating of the total capacitance. The voltage rating should also be selected to be 1.3 times the maximum input voltage. Depending on the unregulated input power source, under light load conditions the maximum input voltage could be significantly higher than normal operation and should be considered when selecting an input capacitor.

The input capacitor should be placed very close to the input pin of the LM2677. Due to relative high current operation with fast transient changes, the series inductance of input connecting wires or PCB traces can create ringing signals at the input terminal which could possibly propagate to the output or other parts of the circuitry. It may be necessary in some designs to add a small valued (0.1µF to 0.47µF) ceramic type capacitor in parallel with the input capacitor to prevent or minimize any ringing.

CATCH DIODE

When the power switch in the LM2677 turns OFF, the current through the inductor continues to flow. The path for this current is through the diode connected between the switch output and ground. This forward biased diode clamps the switch output to a voltage less than ground. This negative voltage must be greater than −1V so a low voltage drop (particularly at high current levels) Schottky diode is recommended. Total efficiency of the entire power supply is significantly impacted by the power lost in the output catch diode. The average current through the catch diode is dependent on the switch duty cycle (D) and is equal to the load current times (1-D). Use of a diode rated for much higher current than is required by the actual application helps to minimize the voltage drop and power loss in the diode.

During the switch ON time the diode will be reversed biased by the input voltage. The reverse voltage rating of the diode should be at least 1.3 times greater than the maximum input voltage.

BOOST CAPACITOR

The boost capacitor creates a voltage used to overdrive the gate of the internal power MOSFET. This improves efficiency by minimizing the on resistance of the switch and associated power loss. For all applications it is recommended to use a 0.01µF/50V ceramic capacitor.

SYNC COMPONENTS

When synchronizing the LM2677 with an external clock it is recommended to connect the clock to pin 5 through a series 100pf capacitor and connect a 1KΩ resistor to ground from pin 5. This RC network creates a short 100nS pulse on each positive edge of the clock to reset the internal ramp oscillator. The reset time of the oscillator is approximately 300nS.

ADDITIONAL APPLICATION INFORMATION

When the output voltage is greater than approximately 6V, and the duty cycle at minimum input voltage is greater than approximately 50%, the designer should exercise caution in selection of the output filter components. When an application designed to these specific operating conditions is subjected to a current limit fault condition, it may be possible to observe a large hysteresis in the current limit. This can affect the output voltage of the device until the load current is reduced sufficiently to allow the current limit protection circuit to reset itself.

Under current limiting conditions, the LM267x is designed to respond in the following manner:

1. At the moment when the inductor current reaches the current limit threshold, the ON-pulse is immediately terminated. This happens for any application condition.
2. However, the current limit block is also designed to momentarily reduce the duty cycle to below 50% to avoid subharmonic oscillations, which could cause the inductor to saturate.
3. Thereafter, once the inductor current falls below the current limit threshold, there is a small relaxation time during which the duty cycle progressively rises back above 50% to the value required to achieve regulation.

If the output capacitance is sufficiently 'large', it may be possible that as the output tries to recover, the output capacitor charging current is large enough to repeatedly re-trigger the current limit circuit before the output has fully settled. This condition is exacerbated with higher output voltage settings because the energy requirement of the output capacitor varies as the square of the output voltage ($½CV^2$), thus requiring an increased charging current.

A simple test to determine if this condition might exist for a suspect application is to apply a short circuit across the output of the converter, and then remove the shorted output condition. In an application with properly selected external components, the output will recover smoothly.

Practical values of external components that have been experimentally found to work well under these specific operating conditions are C_{OUT} = 47µF, L = 22µH. It should be noted that even with these components, for a device's current limit of I_{CLIM}, the maximum load current under which the possibility of the large current limit hysteresis can be minimized is $I_{CLIM}/2$. For example, if the input is 24V and the set output voltage is 18V, then for a desired maximum current of 1.5A, the current limit of the chosen switcher must be confirmed to be at least 3A.

SIMPLE DESIGN PROCEDURE

Using the nomographs and tables in this data sheet (or use the available design software at http://www.national.com) a complete step-down regulator can be designed in a few simple steps.

Step 1: Define the power supply operating conditions:

Required output voltage

Maximum DC input voltage

Maximum output load current

Step 2: Set the output voltage by selecting a fixed output LM2677 (3.3V, 5V or 12V applications) or determine the required feedback resistors for use with the adjustable LM2677 −ADJ

Step 3: Determine the inductor required by using one of the four nomographs, *Figure 3* through *Figure 6*. Table 1 provides a specific manufacturer and part number for the inductor.

Step 4: Using Table 3 (fixed output voltage) or Table 6 (adjustable output voltage), determine the output capacitance required for stable operation. Table 2 provides the specific capacitor type from the manufacturer of choice.

Step 5: Determine an input capacitor from Table 4 for fixed output voltage applications. Use Table 2 to find the specific capacitor type. For adjustable output circuits select a capacitor from Table 2 with a sufficient working voltage (WV) rating greater than Vin max, and an rms current rating greater than one-half the maximum load current (2 or more capacitors in parallel may be required).

Step 6: Select a diode from Table 5. The current rating of the diode must be greater than I load max and the Reverse Voltage rating must be greater than Vin max.

Step 7: Include a 0.01µF/50V capacitor for Cboost in the design.

FIXED OUTPUT VOLTAGE DESIGN EXAMPLE

A system logic power supply bus of 3.3V is to be generated from a wall adapter which provides an unregulated DC voltage of 13V to 16V. The maximum load current is 2.5A. Through-hole components are preferred.

Step 1: Operating conditions are:

Vout = 3.3V

Vin max = 16V

Iload max = 2.5A

Step 2: Select an LM2677T-3.3. The output voltage will have a tolerance of

±2% at room temperature and ±3% over the full operating temperature range.

Step 3: Use the nomograph for the 3.3V device ,*Figure 3*. The intersection of the 16V horizontal line (V_{in} max) and the 2.5A vertical line (I_{load} max) indicates that L33, a 22µH inductor, is required.

From Table 1, L33 in a through-hole component is available from Renco with part number RL-1283-22-43 or part number PE-53933 from Pulse Engineering.

Step 4: Use Table 3 to determine an output capacitor. With a 3.3V output and a 22µH inductor there are four through-hole output capacitor solutions with the number of same type capacitors to be paralleled and an identifying capacitor code given. Table 2 provides the actual capacitor characteristics. Any of the following choices will work in the circuit:

1 x 220µF/10V Sanyo OS-CON (code C5)

1 x 1000µF/35V Sanyo MV-GX (code C10)

1 x 2200µF/10V Nichicon PL (code C5)

1 x 1000µF/35V Panasonic HFQ (code C7)

Step 5: Use Table 4 to select an input capacitor. With 3.3V output and 22µH there are three through-hole solutions. These capacitors provide a sufficient voltage rating and an rms current rating greater than 1.25A (1/2 I_{load} max). Again using Table 2 for specific component characteristics the following choices are suitable:

1 x 1000µF/63V Sanyo MV-GX (code C14)

1 x 820µF/63V Nichicon PL (code C24)

1 x 560µF/50V Panasonic HFQ (code C13)

Step 6: From Table 5 a 3A Schottky diode must be selected. For through-hole components 20V rated diodes are sufficient and 2 part types are suitable:

1N5820

SR302

Step 7: A 0.01µF capacitor will be used for Cboost.

ADJUSTABLE OUTPUT DESIGN EXAMPLE

In this example it is desired to convert the voltage from a two battery automotive power supply (voltage range of 20V to 28V, typical in large truck applications) to the 14.8VDC alternator supply typically used to power electronic equipment from single battery 12V vehicle systems. The load current required is 2A maximum. It is also desired to implement the power supply with all surface mount components.

Step 1: Operating conditions are:

Vout = 14.8V

Vin max = 28V

Iload max = 2A

Step 2: Select an LM2677S-ADJ. To set the output voltage to 14.9V two resistors need to be chosen (R1 and R2 in *Figure 2*). For the adjustable device the output voltage is set by the following relationship:

$$V_{OUT} = V_{FB}\left(1 + \frac{R_2}{R_1}\right)$$

Where V_{FB} is the feedback voltage of typically 1.21V.

A recommended value to use for R1 is 1K. In this example then R2 is determined to be:

$$R_2 = R_1\left(\frac{V_{OUT}}{V_{FB}} - 1\right) = 1\,k\Omega\left(\frac{14.8V}{1.21V} - 1\right)$$

R2 = 11.23KΩ

The closest standard 1% tolerance value to use is 11.3KΩ

This will set the nominal output voltage to 14.88V which is within 0.5% of the target value.

Step 3: To use the nomograph for the adjustable device, *Figure 6*, requires a calculation of the inductor Volt•microsecond constant (E•T expressed in V•µS) from the following formula:

$$E \cdot T = (V_{IN(MAX)} - V_{OUT} - V_{SAT}) \cdot \frac{V_{OUT} + V_D}{V_{IN(MAX)} - V_{SAT} + V_D} \cdot \frac{1000}{260}\ (V \cdot \mu s)$$

where V_{SAT} is the voltage drop across the internal power switch which is $R_{ds(ON)}$ times I_{load}. In this example this would be typically 0.15Ω x 2A or 0.3V and V_D is the voltage drop across the forward bisased Schottky diode, typically 0.5V. The switching frequency of 260KHz is the nominal value to use to estimate the ON time of the switch during which energy is stored in the inductor.

For this example E•T is found to be:

$$E \cdot T = (28 - 14.8 - 0.3) \cdot \frac{14.8 + 0.5}{28 - 0.3 + 0.5} \cdot \frac{1000}{260}\ (V \cdot \mu s)$$

$$E \cdot T = (12.9V) \cdot \frac{15.3}{28.2} \cdot 3.85\ (V \cdot \mu s) = 26.9\ (V \cdot \mu s)$$

Using *Figure 6*, the intersection of 27V•µS horizontally and the 2A vertical line (I_{load} max) indicates that L38 , a 68µH inductor, should be used.

From Table 1, L38 in a surface mount component is available from Pulse Engineering with part number PE-54038S.

Step 4: Use Table 6 to determine an output capacitor. With a 14.8V output the 12.5 to 15V row is used and with a 68µH inductor there are three surface mount output capacitor solutions. Table 2 provides the actual capacitor characteristics based on the C Code number. Any of the following choices can be used:

1 x 33µF/20V AVX TPS (code C6)

1 x 47µF/20V Sprague 594 (code C8)

1 x 47µF/20V Kemet T495 (code C8)

Important Note: When using the adjustable device in low voltage applications (less than 3V output), if the nomograph, Figure 6, selects an inductance of 22µH or less, Table 6 does not provide an output capacitor solution. With these conditions the number of output capacitors required for stable operation becomes impractical. It is recommended to use either a 33µH or 47µH inductor and the output capacitors from Table 6.

Step 5: An input capacitor for this example will require at least a 35V WV rating with an rms current rating of 1A (1/2 Iout max). From Table 2 it can be seen that C12, a 33µF/35V capacitor from Sprague, has the required voltage/current rating of the surface mount components.

Step 6: From Table 5 a 3A Schottky diode must be selected. For surface mount diodes with a margin of safety on the voltage rating one of five diodes can be used:

SK34

30BQ040

30WQ04F

MBRS340

MBRD340

Step 7: A 0.01µF capacitor will be used for Cboost.

LLP PACKAGE DEVICES

The LM2677 is offered in the 14 lead LLP surface mount package to allow for a significantly decreased footprint with equivalent power dissipation compared to the TO-263. For details on mounting and soldering specifications, refer to Application Note AN-1187.

Inductor Selection Guides

For Continuous Mode Operation

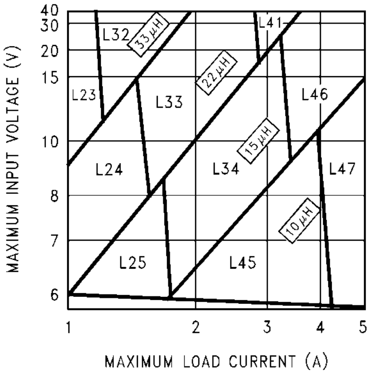


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FIGURE 3. LM2677-3.3

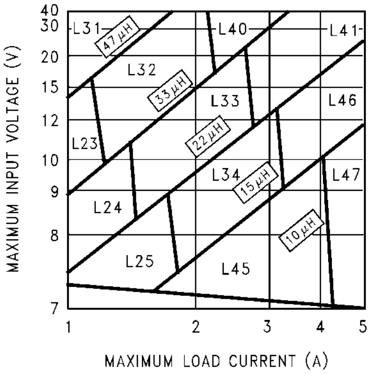

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FIGURE 4. LM2677-5.0

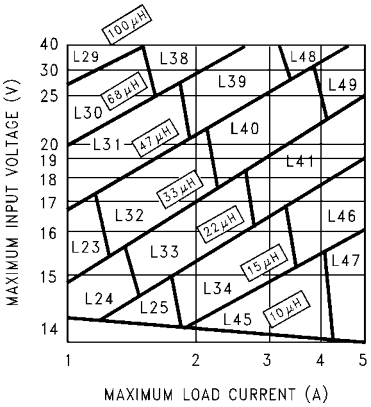

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FIGURE 5. LM2677-12

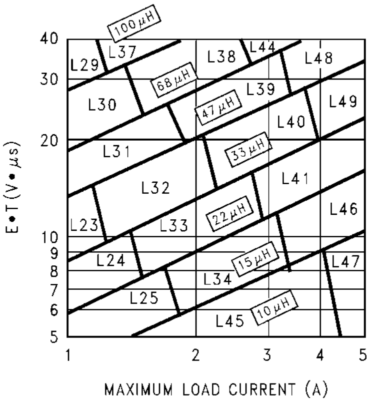

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FIGURE 6. LM2677-ADJ

TABLE 1. Inductor Manufacturer Part Numbers

Inductor Reference Number	Inductance (µH)	Current (A)	Renco		Pulse Engineering		Coilcraft
			Through Hole	Surface Mount	Through Hole	Surface Mount	Surface Mount
L23	33	1.35	RL-5471-7	RL1500-33	PE-53823	PE-53823S	DO3316-333
L24	22	1.65	RL-1283-22-43	RL1500-22	PE-53824	PE-53824S	DO3316-223
L25	15	2.00	RL-1283-15-43	RL1500-15	PE-53825	PE-53825S	DO3316-153
L29	100	1.41	RL-5471-4	RL-6050-100	PE-53829	PE-53829S	DO5022P-104
L30	68	1.71	RL-5471-5	RL6050-68	PE-53830	PE-53830S	DO5022P-683
L31	47	2.06	RL-5471-6	RL6050-47	PE-53831	PE-53831S	DO5022P-473
L32	33	2.46	RL-5471-7	RL6050-33	PE-53932	PE-53932S	DO5022P-333
L33	22	3.02	RL-1283-22-43	RL6050-22	PE-53933	PE-53933S	DO5022P-223
L34	15	3.65	RL-1283-15-43	—	PE-53934	PE-53934S	DO5022P-153
L38	68	2.97	RL-5472-2	—	PE-54038	PE-54038S	—
L39	47	3.57	RL-5472-3	—	PE-54039	PE-54039S	—
L40	33	4.26	RL-1283-33-43	—	PE-54040	PE-54040S	—
L41	22	5.22	RL-1283-22-43	—	PE-54041	P0841	—
L44	68	3.45	RL-5473-3	—	PE-54044	—	—
L45	10	4.47	RL-1283-10-43	—	—	P0845	DO5022P-103HC
L46	15	5.60	RL-1283-15-43	—	—	P0846	DO5022P-153HC
L47	10	5.66	RL-1283-10-43	—	—	P0847	DO5022P-103HC
L48	47	5.61	RL-1282-47-43	—	—	P0848	—
L49	33	5.61	RL-1282-33-43	—	—	P0849	—

Inductor Manufacturer Contact Numbers

Coilcraft	Phone	(800) 322-2645
	FAX	(708) 639-1469
Coilcraft, Europe	Phone	+44 1236 730 595
	FAX	+44 1236 730 627
Pulse Engineering	Phone	(619) 674-8100
	FAX	(619) 674-8262
Pulse Engineering, Europe	Phone	+353 93 24 107
	FAX	+353 93 24 459
Renco Electronics	Phone	(800) 645-5828
	FAX	(516) 586-5562

Capacitor Selection Guides

TABLE 2. Input and Output Capacitor Codes

Capacitor Reference Code	Surface Mount								
	AVX TPS Series			Sprague 594D Series			Kemet T495 Series		
	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)
C1	330	6.3	1.15	120	6.3	1.1	100	6.3	0.82
C2	100	10	1.1	220	6.3	1.4	220	6.3	1.1
C3	220	10	1.15	68	10	1.05	330	6.3	1.1
C4	47	16	0.89	150	10	1.35	100	10	1.1
C5	100	16	1.15	47	16	1	150	10	1.1
C6	33	20	0.77	100	16	1.3	220	10	1.1
C7	68	20	0.94	180	16	1.95	33	20	0.78
C8	22	25	0.77	47	20	1.15	47	20	0.94
C9	10	35	0.63	33	25	1.05	68	20	0.94
C10	22	35	0.66	68	25	1.6	10	35	0.63
C11				15	35	0.75	22	35	0.63
C12				33	35	1	4.7	50	0.66
C13				15	50	0.9			

Input and Output Capacitor Codes (continued)

Capacitor Reference Code	Through Hole											
	Sanyo OS-CON SA Series			Sanyo MV-GX Series			Nichicon PL Series			Panasonic HFQ Series		
	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)
C1	47	6.3	1	1000	6.3	0.8	680	10	0.8	82	35	0.4
C2	150	6.3	1.95	270	16	0.6	820	10	0.98	120	35	0.44
C3	330	6.3	2.45	470	16	0.75	1000	10	1.06	220	35	0.76
C4	100	10	1.87	560	16	0.95	1200	10	1.28	330	35	1.01
C5	220	10	2.36	820	16	1.25	2200	10	1.71	560	35	1.4
C6	33	16	0.96	1000	16	1.3	3300	10	2.18	820	35	1.62
C7	100	16	1.92	150	35	0.65	3900	10	2.36	1000	35	1.73
C8	150	16	2.28	470	35	1.3	6800	10	2.68	2200	35	2.8
C9	100	20	2.25	680	35	1.4	180	16	0.41	56	50	0.36
C10	47	25	2.09	1000	35	1.7	270	16	0.55	100	50	0.5
C11				220	63	0.76	470	16	0.77	220	50	0.92
C12				470	63	1.2	680	16	1.02	470	50	1.44
C13				680	63	1.5	820	16	1.22	560	50	1.68
C14				1000	63	1.75	1800	16	1.88	1200	50	2.22
C15							220	25	0.63	330	63	1.42
C16							220	35	0.79	1500	63	2.51
C17							560	35	1.43			
C18							2200	35	2.68			
C19							150	50	0.82			
C20							220	50	1.04			
C21							330	50	1.3			
C22							100	63	0.75			
C23							390	63	1.62			
C24							820	63	2.22			
C25							1200	63	2.51			

Capacitor Manufacturer Contact Numbers

Nichicon	Phone	(847) 843-7500
	FAX	(847) 843-2798
Panasonic	Phone	(714) 373-7857
	FAX	(714) 373-7102
AVX	Phone	(845) 448-9411
	FAX	(845) 448-1943
Sprague/Vishay	Phone	(207) 324-4140
	FAX	(207) 324-7223
Sanyo	Phone	(619) 661-6322
	FAX	(619) 661-1055
Kemet	Phone	(864) 963-6300
	FAX	(864) 963-6521

TABLE 3. Output Capacitors for Fixed Output Voltage Application

Output Voltage (V)	Inductance (μH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
3.3	10	5	C1	5	C1	5	C2
	15	4	C1	4	C1	4	C3
	22	3	C2	2	C7	3	C4
	33	1	C1	2	C7	3	C4
5	10	4	C2	4	C6	4	C4
	15	3	C3	2	C7	3	C5
	22	3	C2	2	C7	3	C4
	33	2	C2	2	C3	2	C4
	47	2	C2	1	C7	2	C4
12	10	4	C5	3	C6	5	C9
	15	3	C5	2	C7	4	C9
	22	2	C5	2	C6	3	C8
	33	2	C5	1	C7	3	C8
	47	2	C4	1	C6	2	C8
	68	1	C5	1	C5	2	C7
	100	1	C4	1	C5	1	C8

Output Voltage (V)	Inductance (μH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
3.3	10	2	C5	2	C6	1	C8	2	C6
	15	2	C5	2	C5	1	C7	2	C5
	22	1	C5	1	C10	1	C5	1	C7
	33	1	C5	1	C10	1	C5	1	C7
5	10	2	C4	2	C5	1	C6	2	C5
	15	1	C5	1	C10	1	C5	1	C7
	22	1	C5	1	C9	1	C5	1	C5
	33	1	C4	1	C5	1	C4	1	C4
	47	1	C4	1	C4	1	C2	2	C4
12	10	2	C7	1	C10	1	C14	2	C4
	15	1	C8	1	C6	1	C17	1	C5
	22	1	C7	1	C5	1	C13	1	C5
	33	1	C7	1	C4	1	C12	1	C4
	47	1	C7	1	C3	1	C11	1	C3
	68	1	C6	1	C2	1	C10	1	C3
	100	1	C6	1	C2	1	C9	1	C1

No. represents the number of identical capacitor types to be connected in parallel
C Code indicates the Capacitor Reference number in *Table 2*for identifying the specific component from the manufacturer.

TABLE 4. Input Capacitors for Fixed Output Voltage Application

(Assumes worst case maximum input voltage and load current for a given inductance value)

Output Voltage (V)	Inductance (μH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
3.3	10	3	C7	2	C10	3	C9
	15	*	*	3	C13	4	C12
	22	*	*	2	C13	3	C12
	33	*	*	2	C13	3	C12
5	10	3	C4	2	C6	3	C9
	15	4	C9	3	C12	4	C10
	22	*	*	3	C13	4	C12
	33	*	*	2	C13	3	C12
	47	*	*	1	C13	2	C12
12	10	4	C9	2	C10	4	C10
	15	4	C8	2	C10	4	C10
	22	4	C9	3	C12	4	C10
	33	*	*	3	C13	4	C12
	47	*	*	2	C13	3	C12
	68	*	*	2	C13	2	C12
	100	*	*	1	C13	2	C12

Output Voltage (V)	Inductance (μH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
3.3	10	2	C9	2	C8	1	C18	1	C8
	15	*	*	2	C13	1	C25	1	C16
	22	*	*	1	C14	1	C24	1	C16
	33	*	*	1	C14	1	C24	1	C16
5	10	2	C7	2	C8	1	C25	1	C8
	15	*	*	2	C8	1	C25	1	C8
	22	*	*	2	C13	1	C25	1	C16
	33	*	*	1	C14	1	C23	1	C13
	47	*	*	1	C12	1	C19	1	C11
12	10	2	C10	2	C8	1	C18	1	C8
	15	2	C10	2	C8	1	C18	1	C8
	22	*	*	2	C8	1	C18	1	C8
	33	*	*	2	C12	1	C24	1	C14
	47	*	*	1	C14	1	C23	1	C13
	68	*	*	1	C13	1	C21	1	C15
	100	*	*	1	C11	1	C22	1	C11

* Check voltage rating of capacitors to be greater than application input voltage.
No. represents the number of identical capacitor types to be connected in parallel
C Code indicates the Capacitor Reference number in *Table 2* for identifying the specific component from the manufacturer.

TABLE 5. Schottky Diode Selection Table

Reverse Voltage (V)	Surface Mount		Through Hole	
	3A	5A or More	3A	5A or More
20V	SK32		1N5820 SR302	
30V	SK33 30WQ03F	MBRD835L	1N5821 31DQ03	
40V	SK34 30BQ040 30WQ04F MBRS340 MBRD340	MBRB1545CT 6TQ045S	1N5822 MBR340 31DQ04 SR403	MBR745 80SQ045 6TQ045
50V or More	SK35 30WQ05F		MBR350 31DQ05 SR305	

Diode Manufacturer Contact Numbers

International Rectifier	Phone	(310) 322-3331
	FAX	(310) 322-3332
Motorola	Phone	(800) 521-6274
	FAX	(602) 244-6609
General Semiconductor	Phone	(516) 847-3000
	FAX	(516) 847-3236
Diodes, Inc.	Phone	(805) 446-4800
	FAX	(805) 446-4850

TABLE 6. Output Capacitors for Adjustable Output Voltage Applications

Output Voltage (V)	Inductance (µH)	Surface Mount					
		AVX TPS Series		Sprague 594D Series		Kemet T495 Series	
		No.	C Code	No.	C Code	No.	C Code
1.21 to 2.50	33*	7	C1	6	C2	7	C3
	47*	5	C1	4	C2	5	C3
2.5 to 3.75	33*	4	C1	3	C2	4	C3
	47*	3	C1	2	C2	3	C3
3.75 to 5	22	4	C1	3	C2	4	C3
	33	3	C1	2	C2	3	C3
	47	2	C1	2	C2	2	C3
5 to 6.25	22	3	C2	1	C3	3	C4
	33	2	C2	2	C3	2	C4
	47	2	C2	2	C3	2	C4
	68	1	C2	1	C3	1	C4
6.25 to 7.5	22	3	C2	1	C4	3	C4
	33	2	C2	1	C3	2	C4
	47	1	C3	1	C4	1	C6
	68	1	C2	1	C3	1	C4
7.5 to 10	33	2	C5	1	C6	2	C8
	47	1	C5	1	C6	2	C8
	68	1	C5	1	C6	1	C8
	100	1	C4	1	C5	1	C8
10 to 12.5	33	1	C5	1	C6	2	C8
	47	1	C5	1	C6	2	C8
	68	1	C5	1	C6	1	C8
	100	1	C5	1	C6	1	C8
12.5 to 15	33	1	C6	1	C8	1	C8
	47	1	C6	1	C8	1	C8
	68	1	C6	1	C8	1	C8
	100	1	C6	1	C8	1	C8
15 to 20	33	1	C8	1	C10	2	C10
	47	1	C8	1	C9	2	C10
	68	1	C8	1	C9	2	C10
	100	1	C8	1	C9	1	C10
20 to 30	33	2	C9	2	C11	2	C11
	47	1	C10	1	C12	1	C11
	68	1	C9	1	C12	1	C11
	100	1	C9	1	C12	1	C11
30 to 37	10	No Values Available		4	C13	8	C12
	15			3	C13	5	C12
	22			2	C13	4	C12
	33			1	C13	3	C12
	47			1	C13	2	C12
	68			1	C13	2	C12

Output Capacitors for Adjustable Output Voltage Applications (continued)

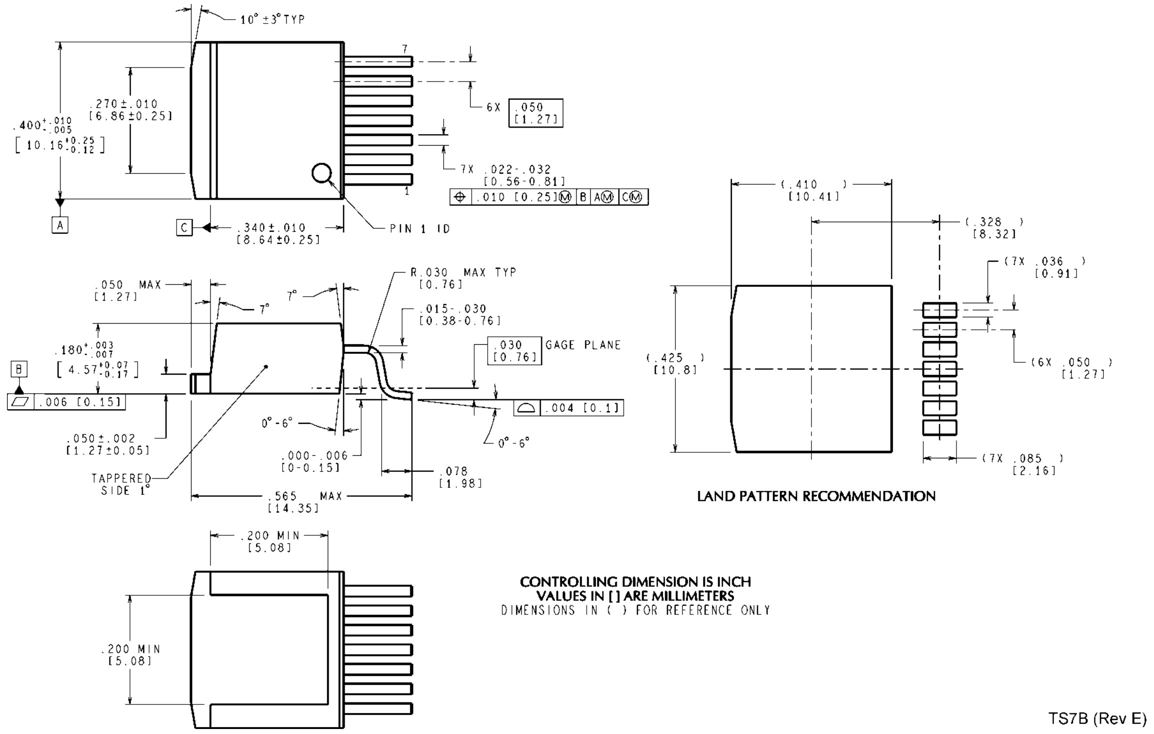
Output Voltage (V)	Inductance (µH)	Through Hole							
		Sanyo OS-CON SA Series		Sanyo MV-GX Series		Nichicon PL Series		Panasonic HFQ Series	
		No.	C Code	No.	C Code	No.	C Code	No.	C Code
1.21 to 2.50	33*	2	C3	5	C1	5	C3	3	C
	47*	2	C2	4	C1	3	C3	2	C5
2.5 to 3.75	33*	1	C3	3	C1	3	C1	2	C5
	47*	1	C2	2	C1	2	C3	1	C5
3.75 to 5	22	1	C3	3	C1	3	C1	2	C5
	33	1	C2	2	C1	2	C1	1	C5
	47	1	C2	2	C1	1	C3	1	C5
5 to 6.25	22	1	C5	2	C6	2	C3	2	C5
	33	1	C4	1	C6	2	C1	1	C5
	47	1	C4	1	C6	1	C3	1	C5
	68	1	C4	1	C6	1	C1	1	C5
6.25 to 7.5	22	1	C5	1	C6	2	C1	1	C5
	33	1	C4	1	C6	1	C3	1	C5
	47	1	C4	1	C6	1	C1	1	C5
	68	1	C4	1	C2	1	C1	1	C5
7.5 to 10	33	1	C7	1	C6	1	C14	1	C5
	47	1	C7	1	C6	1	C14	1	C5
	68	1	C7	1	C2	1	C14	1	C2
	100	1	C7	1	C2	1	C14	1	C2
10 to 12.5	33	1	C7	1	C6	1	C14	1	C5
	47	1	C7	1	C2	1	C14	1	C5
	68	1	C7	1	C2	1	C9	1	C2
	100	1	C7	1	C2	1	C9	1	C2
12.5 to 15	33	1	C9	1	C10	1	C15	1	C2
	47	1	C9	1	C10	1	C15	1	C2
	68	1	C9	1	C10	1	C15	1	C2
	100	1	C9	1	C10	1	C15	1	C2
15 to 20	33	1	C10	1	C7	1	C15	1	C2
	47	1	C10	1	C7	1	C15	1	C2
	68	1	C10	1	C7	1	C15	1	C2
	100	1	C10	1	C7	1	C15	1	C2
20 to 30	33	No Values Available		1	C7	1	C16	1	C2
	47			1	C7	1	C16	1	C2
	68			1	C7	1	C16	1	C2
	100			1	C7	1	C16	1	C2
30 to 37	10	No Values Available		1	C12	1	C20	1	C10
	15			1	C11	1	C20	1	C11
	22			1	C11	1	C20	1	C10
	33			1	C11	1	C20	1	C10
	47			1	C11	1	C20	1	C10
	68			1	C11	1	C20	1	C10

* Set to a higher value for a practical design solution. See Applications Hints section

No. represents the number of identical capacitor types to be connected in parallel

C Code indicates the Capacitor Reference number in *Table 2* for identifying the specific component from the manufacturer.

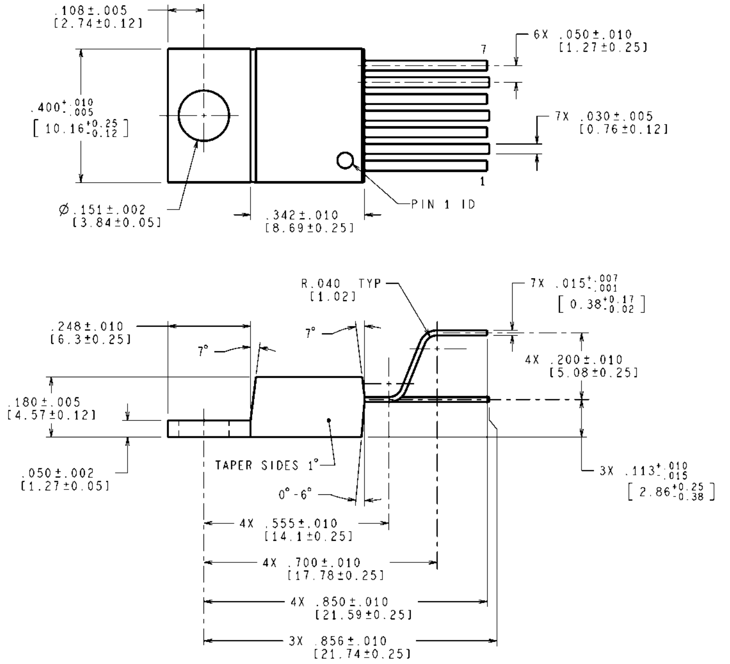
Physical Dimensions inches (millimeters) unless otherwise noted



CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS
DIMENSIONS IN ( ) FOR REFERENCE ONLY

TS7B (Rev E)

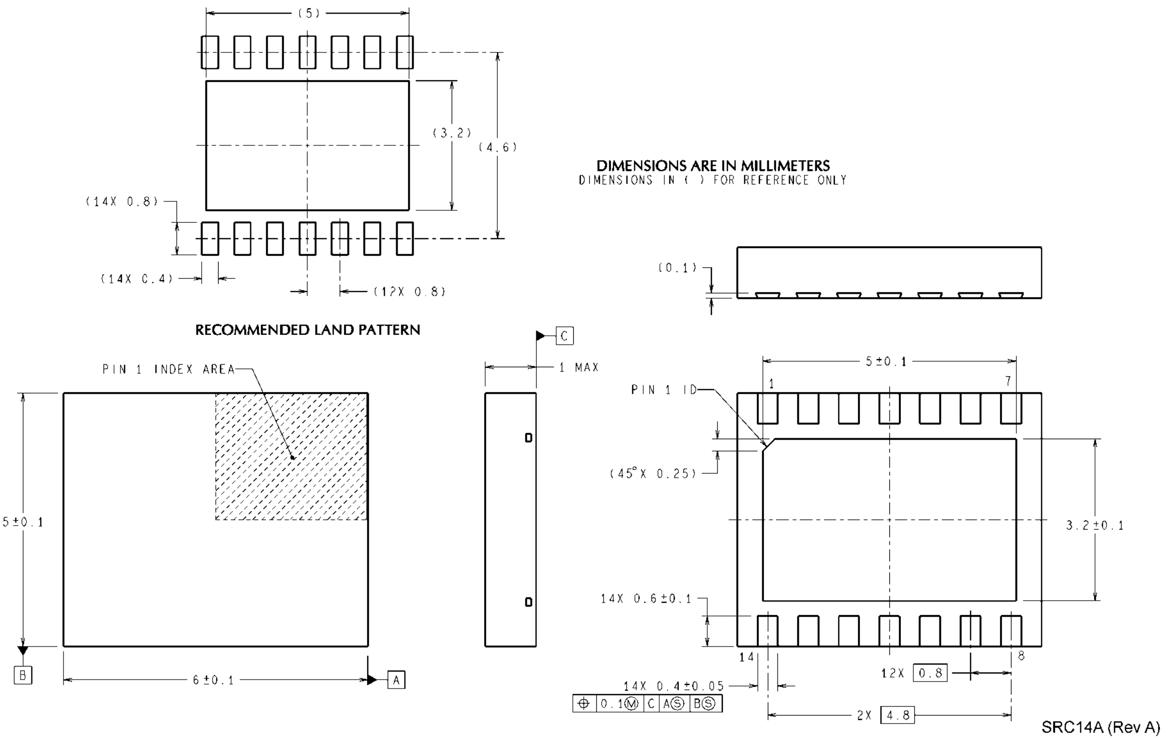
TO-263 Surface Mount Power Package
Order Number LM2677S-3.3, LM2677S-5.0,
LM2677S-12 or LM2677S-ADJ
NS Package Number TS7B



CONTROLING DIMENSIONS IS INCH
VALUES IN [ ] ARE MILLIMETERS

TA07B (Rev E)

TO-220 Power Package
Order Number LM2677T-3.3, LM2677T-5.0,
LM2677T-12 or LM2677T-ADJ
NS Package Number TA07B



SRC14A (Rev A)

14-Lead LLP Package
NS Package Number SRC14A

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