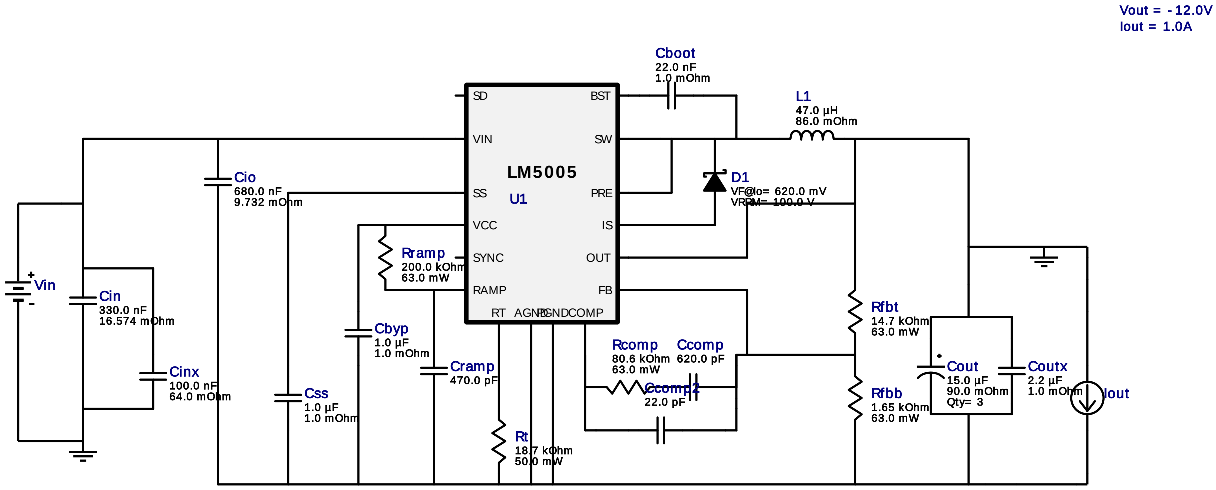
TEXAS INSTRUMENTS

VinMin = 24.0V
VinMax = 32.0V
Vout = -12.0V
Iout = 1.0A

Device = LM5005MHX/NOPB
Topology = Inverting_Buck_Boost
Created = 2019-11-14 08:01:16.337
BOM Cost = $4.75
BOM Count = 21
Total Pd = 1.64W

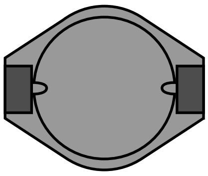
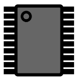
WEBENCH ® Design Report

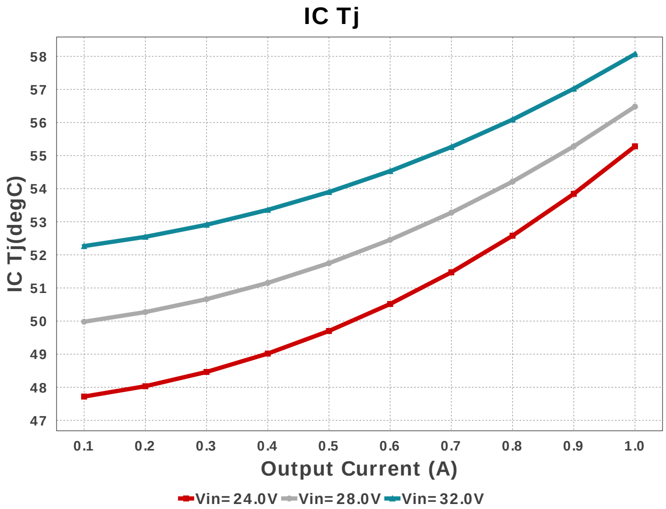
Design : 23 LM5005MHX/NOPB
LM5005MHX/NOPB 24V-32V to -12.00V @ 1A

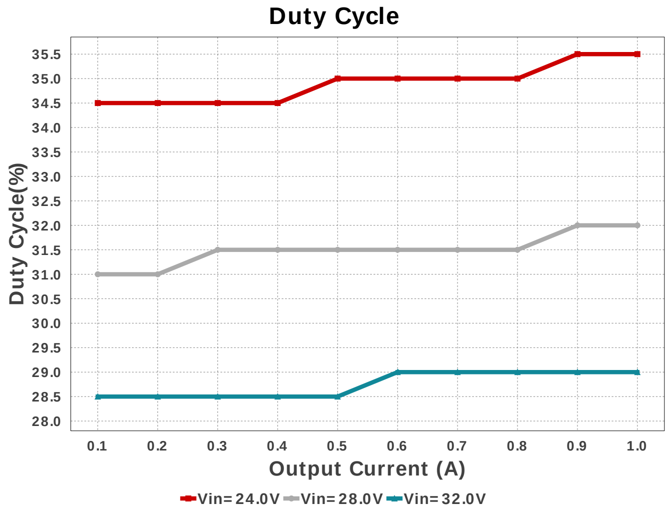


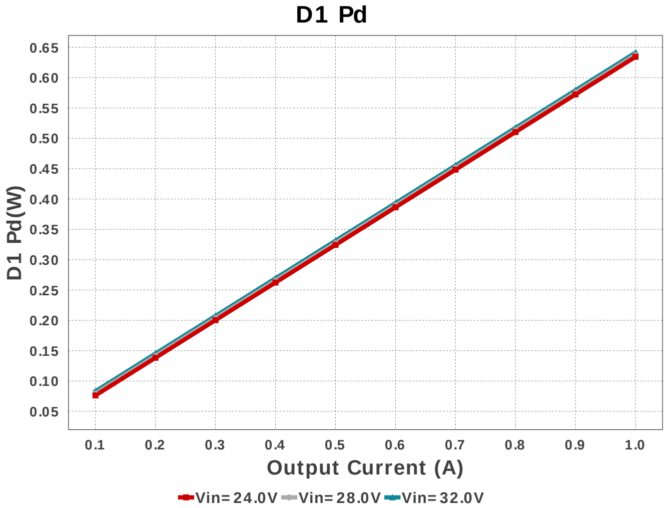
Electrical BOM

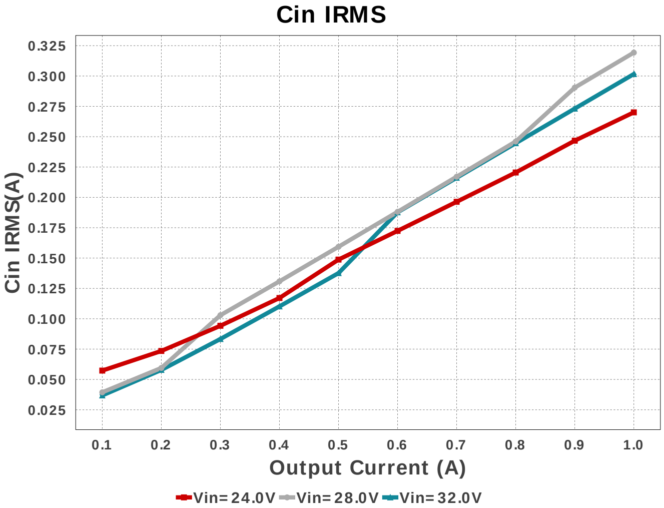
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cboot	MuRata	GRM155R71H223KA12D Series= X7R	Cap= 22.0 nF ESR= 1.0 mOhm VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm²
Cbyp	Taiyo Yuden	EMK107B7105KA-T Series= X7R	Cap= 1.0 uF ESR= 1.0 mOhm VDC= 16.0 V IRMS= 0.0 A	1	$0.02	0603 5 mm²
Ccomp	Samsung Electro-Mechanics	CL21C621JBCNNNC Series= C0G/NP0	Cap= 620.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.10	0805 7 mm²
Ccomp2	Samsung Electro-Mechanics	CL21C220JBANNNC Series= C0G/NP0	Cap= 22.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm²
Cin	TDK	C1608X5R1H334K080AB Series= X5R	Cap= 330.0 nF ESR= 16.574 mOhm VDC= 50.0 V IRMS= 1.28367 A	1	$0.04	0603 5 mm²
Cinx	Kemet	C0805C104M5RACTU Series= X7R	Cap= 100.0 nF ESR= 64.0 mOhm VDC= 50.0 V IRMS= 1.64 A	1	$0.01	0805 7 mm²
Cio	TDK	C2012X7S2A684K125AB Series= X7S	Cap= 680.0 nF ESR= 9.732 mOhm VDC= 100.0 V IRMS= 2.0961 A	1	$0.10	0805 7 mm²
Cout	Panasonic	16TQC15M Series= TQC	Cap= 15.0 uF ESR= 90.0 mOhm VDC= 16.0 V IRMS= 1.0 A	3	$0.70	3528-21 17 mm²
Coutx	Taiyo Yuden	TMK212BJ225KG-T Series= X5R	Cap= 2.2 uF ESR= 1.0 mOhm VDC= 20.0 V IRMS= 0.0 A	1	$0.04	0805 7 mm²

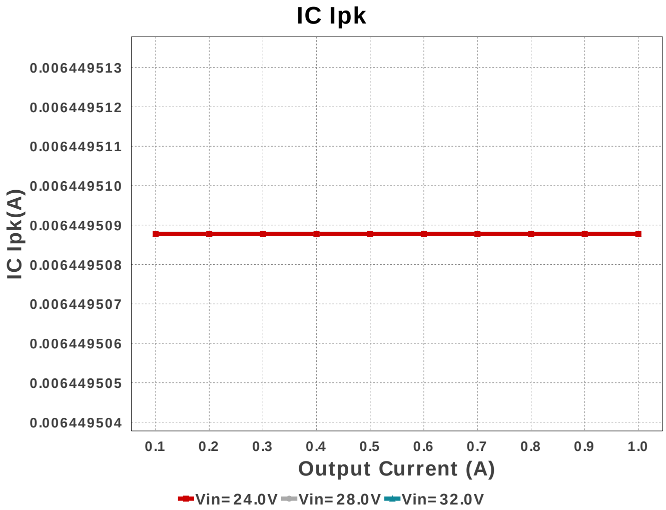
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cramp	Samsung Electro-Mechanics	CL21C471KBANNNC Series= C0G/NP0	Cap= 470.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm²
Css	Taiyo Yuden	EMK107B7105KA-T Series= X7R	Cap= 1.0 uF ESR= 1.0 mOhm VDC= 16.0 V IRMS= 0.0 A	1	$0.02	0603 5 mm²
D1	Vishay-Semiconductor	SS2PH10-M3	VF@Io= 620.0 mV VRRM= 100.0 V	1	$0.14	DO-220AA 14 mm²
L1	NIC Components	NPI52W470MTRF	L= 47.0 µH 86.0 mOhm	1	$0.35	 IND_NPI52W 358 mm²
Rcomp	Vishay-Dale	CRCW040280K6FKED Series= CRCW..e3	Res= 80.6 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rfbb	Vishay-Dale	CRCW04021K65FKED Series= CRCW..e3	Res= 1.65 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rfbt	Vishay-Dale	CRCW040214K7FKED Series= CRCW..e3	Res= 14.7 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rramp	Vishay-Dale	CRCW0402200KFKED Series= CRCW..e3	Res= 200.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rt	Yageo	RC0201FR-0718K7L Series= ?	Res= 18.7 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm²
U1	Texas Instruments	LM5005MHX/NOPB	Switcher	1	$1.75	 MXA20A 71 mm²

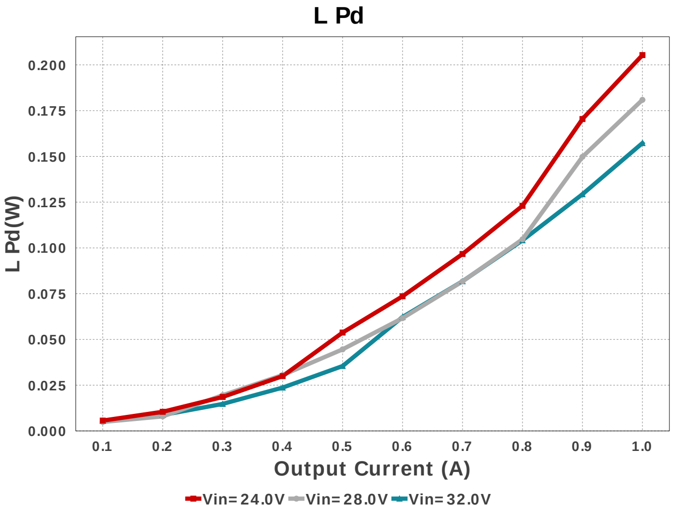


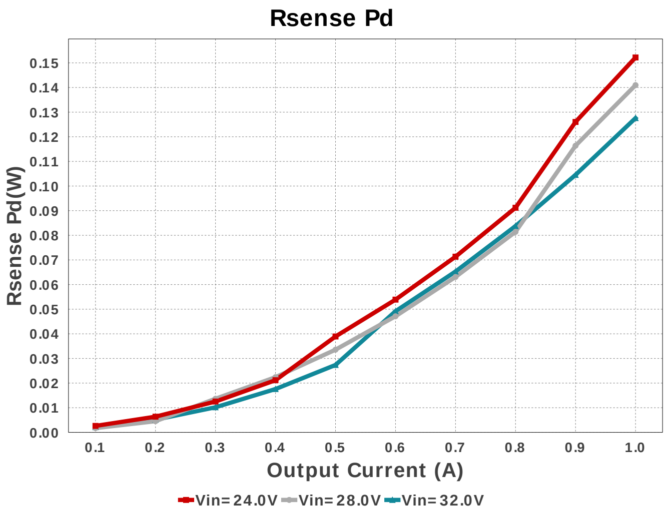


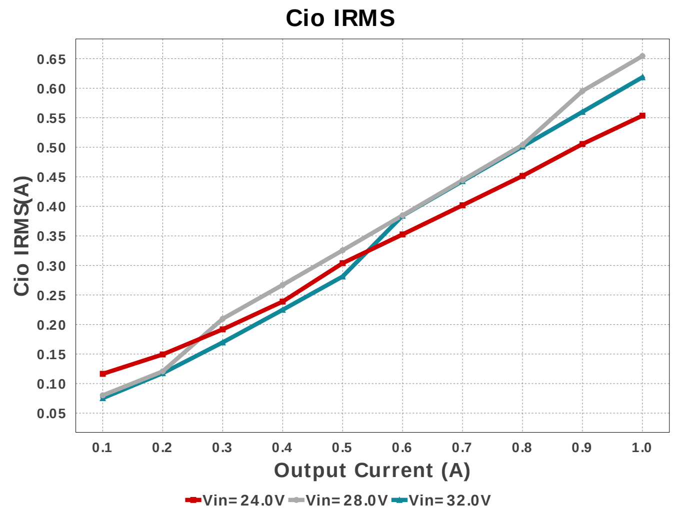

D1 Pd
D1 Pd(W)
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V

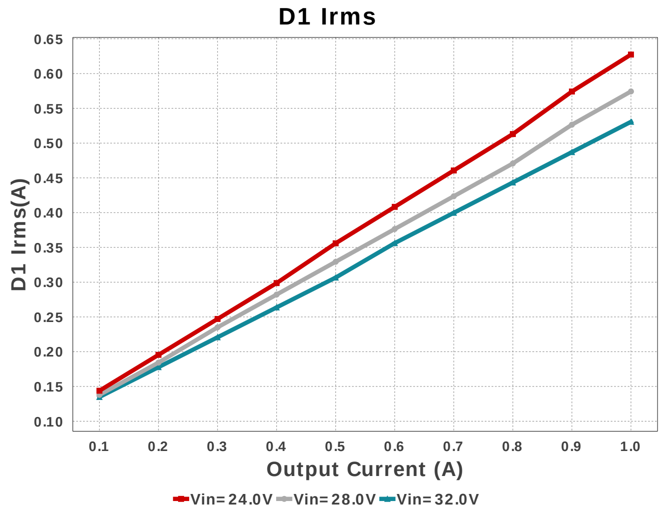

Cin IRMS
Cin IRMS(A)
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V

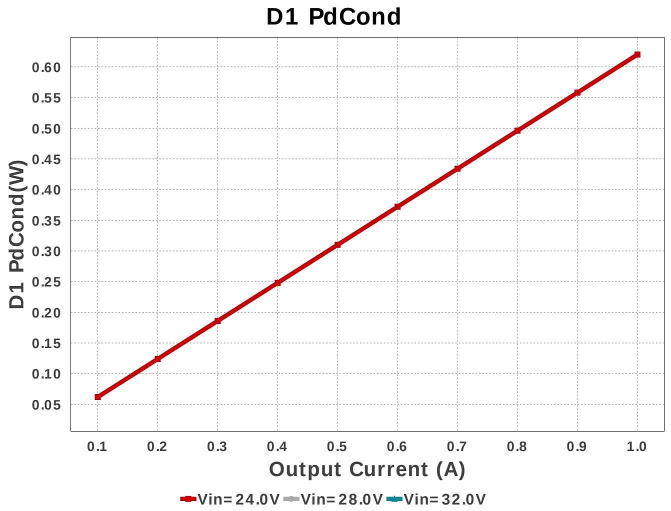

IC Ipk
IC Ipk(A)
0.006449513
0.006449512
0.006449511
0.006449510
0.006449509
0.006449508
0.006449507
0.006449506
0.006449505
0.006449504
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V

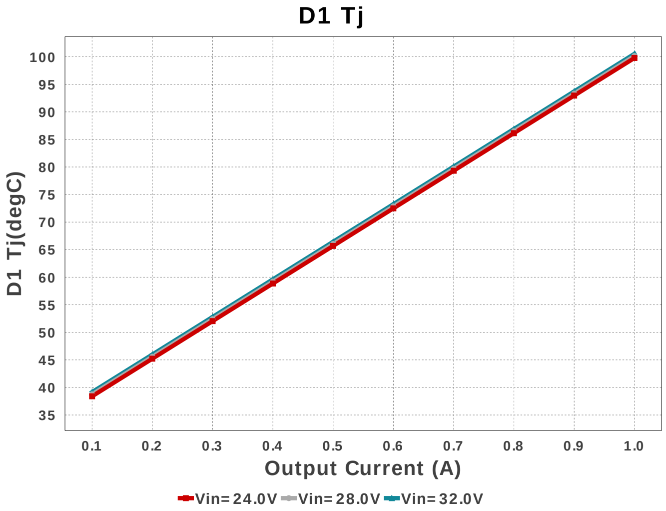

L Pd
L Pd(W)
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V

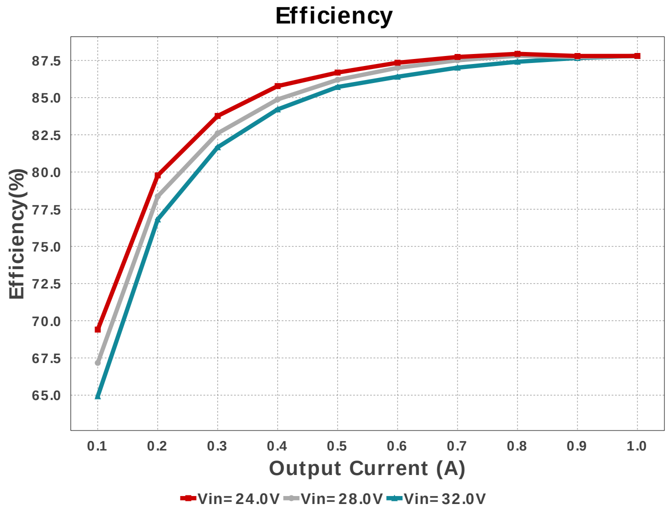

Rsense Pd
Rsense Pd(W)
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V

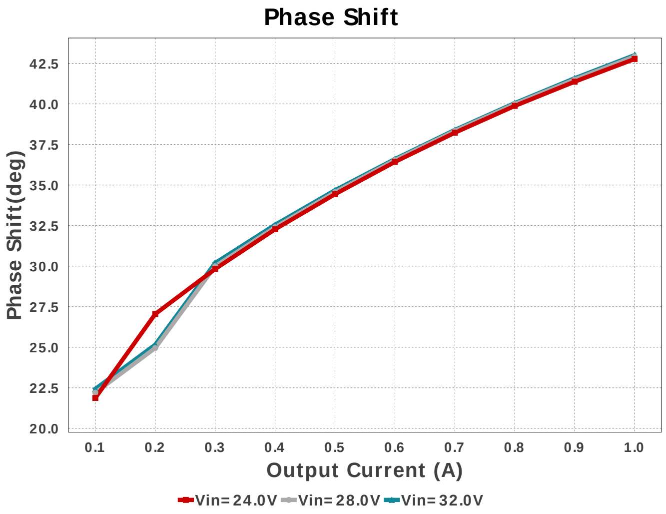

Cio IRMS
Cio IRMS(A)
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V

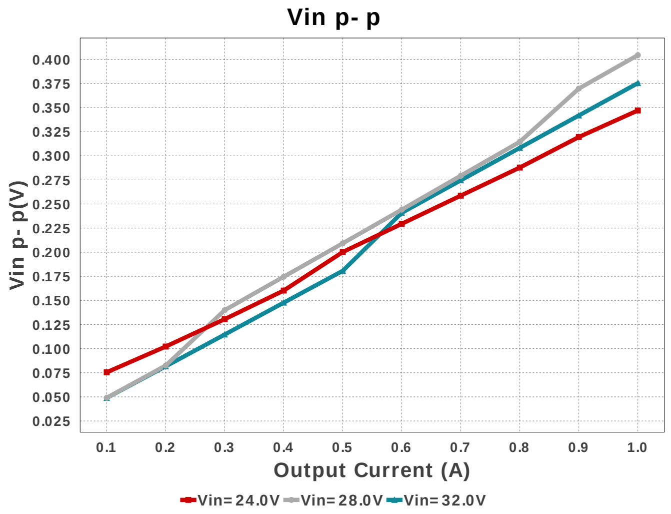

D1 Irms
D1 Irms(A)
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

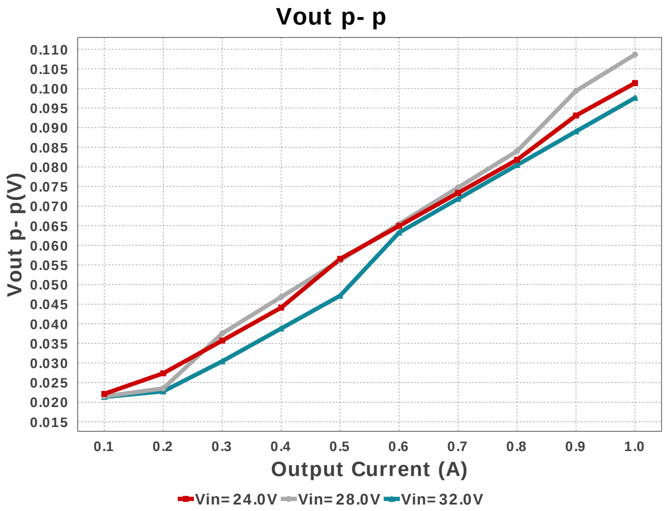

D1 PdCond
D1 PdCond(W)
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

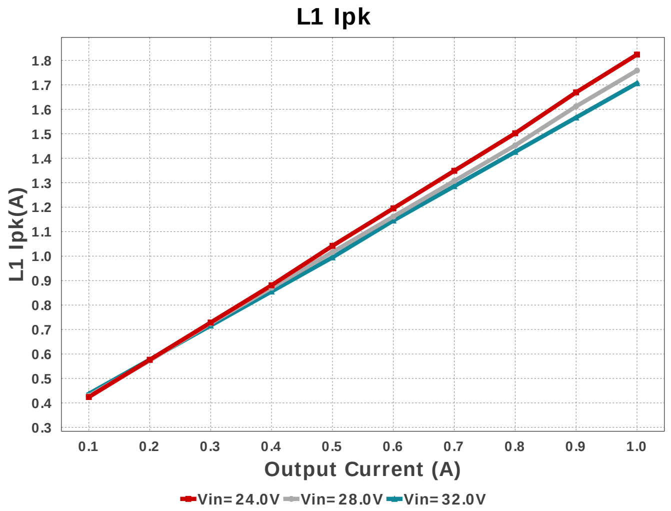

D1 Tj
D1 Tj(degC)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

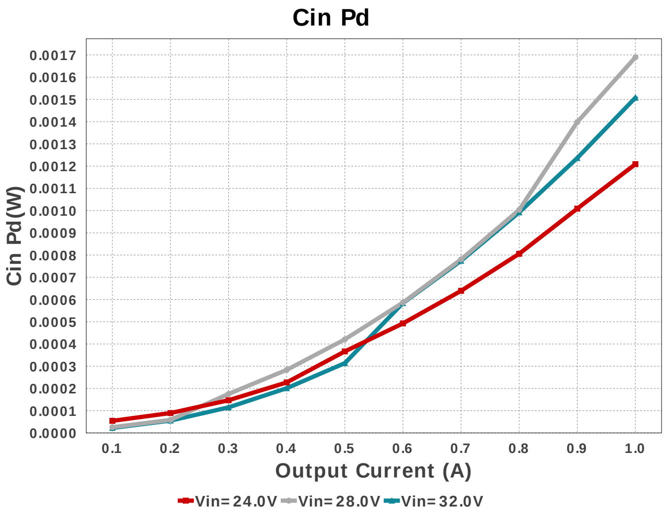

Efficiency
Efficiency(%)
87.5
85.0
82.5
80.0
77.5
75.0
72.5
70.0
67.5
65.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

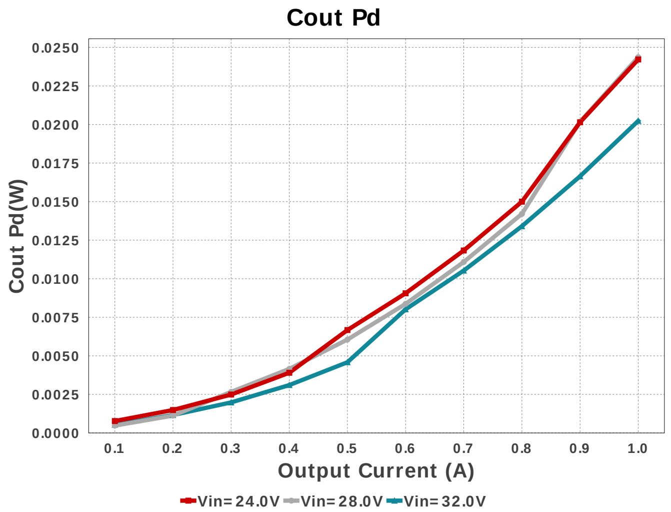

Phase Shift
Phase Shift(deg)
42.5
40.0
37.5
35.0
32.5
30.0
27.5
25.0
22.5
20.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

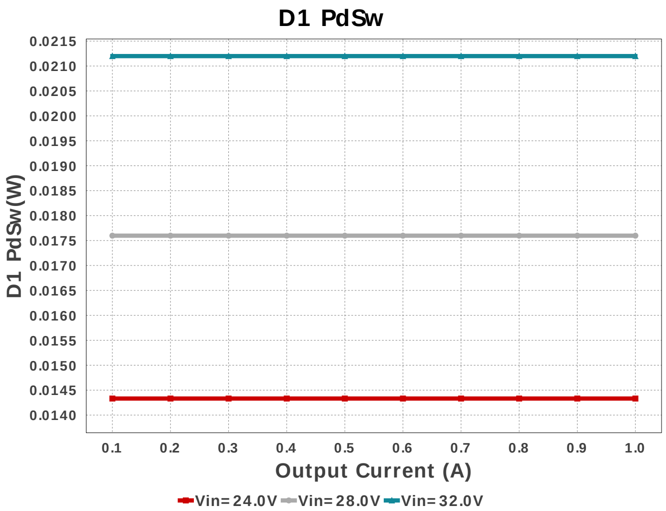

Vin p- p
Vin p- p(V)
0.400
0.375
0.350
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

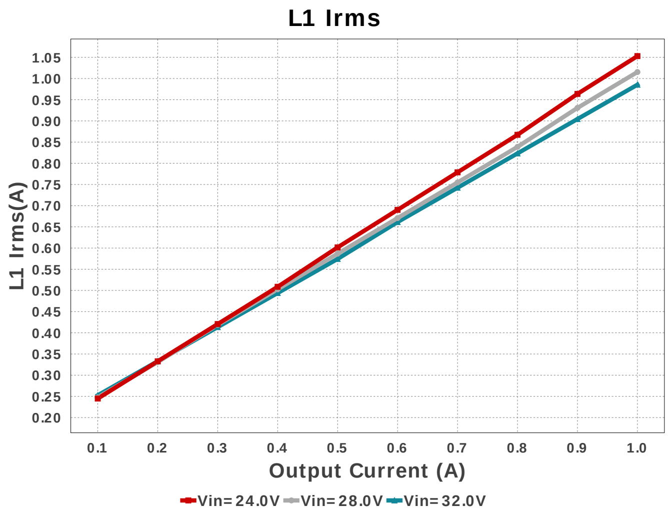

Vout p- p
Vout p- p(V)
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

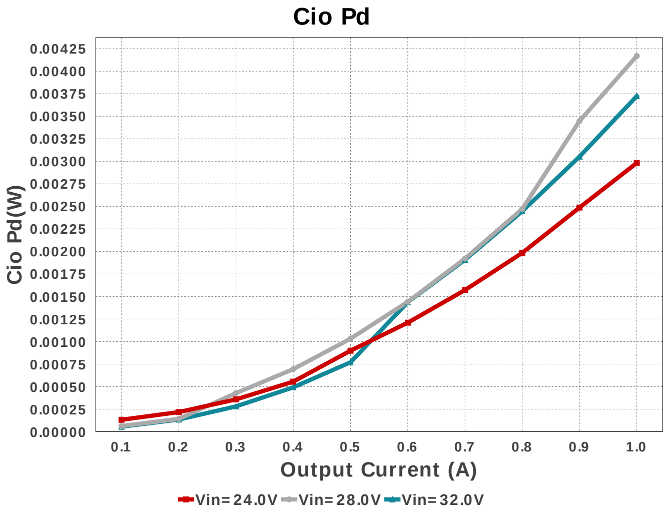

L1 Ipk
L1 Ipk(A)
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

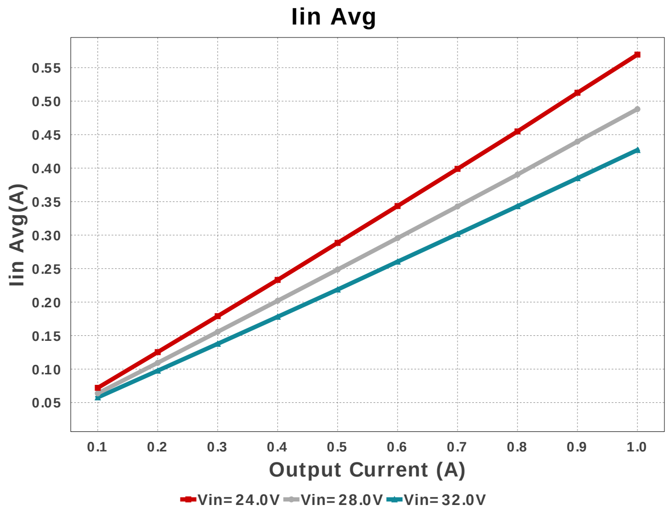

Cin Pd
Cin Pd(W)
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

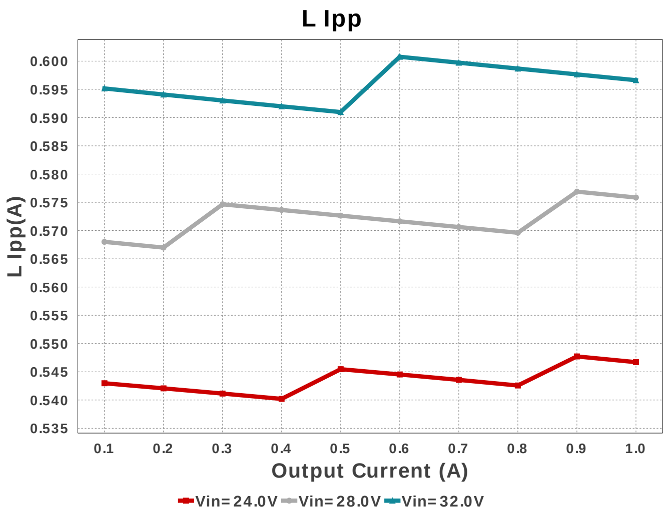

Cout Pd
Cout Pd(W)
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

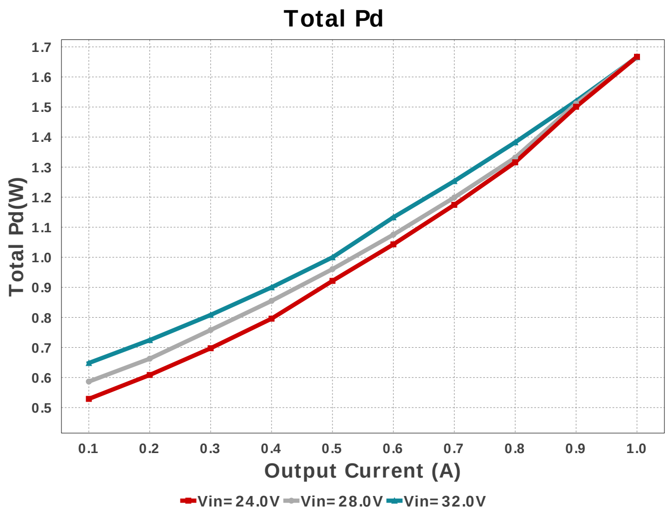

D1 PdSw
D1 PdSw(W)
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

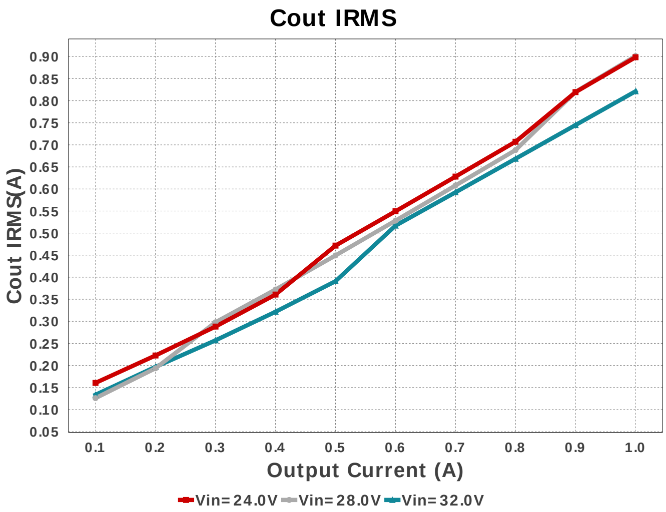

L1 Irms
L1 Irms(A)
Output Current (A)
Vin= 24.0V
Vin= 28.0V
Vin= 32.0V

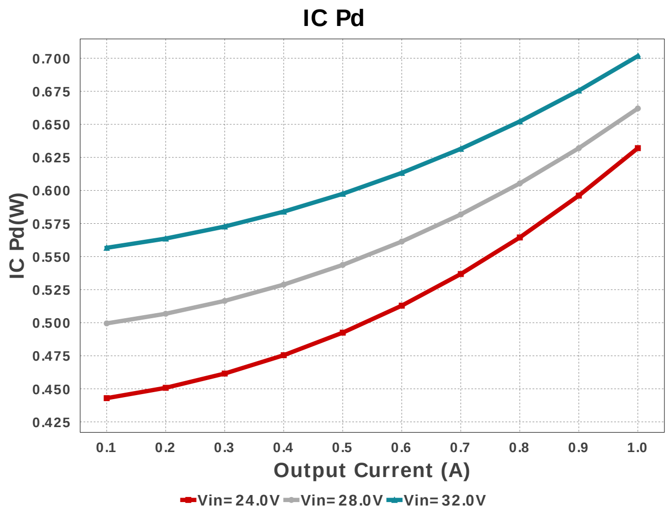

Cio Pd
Cio Pd(W)
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V

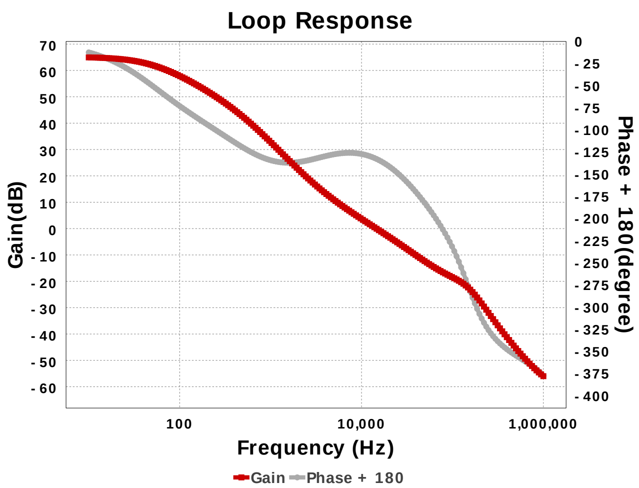

Iin Avg
Iin Avg(A)
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V


L Ipp
L Ipp(A)
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V


Total Pd
Total Pd(W)
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V


Cout IRMS
Cout IRMS(A)
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V


IC Pd
IC Pd(W)
Output Current (A)
Vin=24.0V Vin=28.0V Vin=32.0V



Operating Values

#	Name	Value	Category	Description
1.	Cin IRMS	236.277 mA	Capacitor	Input capacitor RMS ripple current
2.	Cin Pd	925.275 µW	Capacitor	Input capacitor power dissipation
3.	Cio IRMS	482.846 mA	Capacitor	Input to output capacitor RMS ripple current
4.	Cio Pd	2.269 mW	Capacitor	Input to output capacitor power dissipation
5.	Cout IRMS	771.994 mA	Capacitor	Output capacitor RMS ripple current
6.	Cout Pd	17.879 mW	Capacitor	Output capacitor power dissipation
7.	D1 Irms	537.231 mA	Current	D1 Irms
8.	D1 Pd	639.744 mW	Diode	Diode power dissipation
9.	D1 PdCond	620.0 mW	Diode	Diode conduction losses
10.	D1 PdSw	19.744 mW	Diode	Diode switching losses
11.	D1 Tj	100.372 degC	Diode	D1 junction temperature
12.	IC Ipk	6.35 mA	IC	Peak switch current in IC
13.	IC Pd	687.82 mW	IC	IC power dissipation
14.	IC Tj	57.513 degC	IC	IC junction temperature
15.	IC Tolerance	18.0 mV	IC	IC Feedback Tolerance
16.	Iin Avg	426.18 mA	IC	Average input current
17.	L Ipp	638.932 mA	Inductor	Peak-to-peak output inductor ripple current
18.	L Pd	153.999 mW	Inductor	Inductor power dissipation
19.	L1 Ipk	1.728 A	Inductor	Inductor peak current
20.	L1 Irms	997.613 mA	Inductor	Inductor ripple current
21.	IOUT_OP	1.0 A	Op Point	Iout operating point
22.	VIN_OP	24.0 V	Op Point	Vin operating point
23.	Total Pd	1.638 W	Power	Total Power Dissipation
24.	Rsense Pd	124.798 mW	Resistor	LED Current Rsns Power Dissipation
25.	BOM Count	21	System Information	Total Design BOM count
26.	Cross Freq	13.826 kHz	System Information	Bode plot crossover frequency
27.	Duty Cycle	29.0 %	System Information	Duty cycle
28.	Efficiency	87.991 %	System Information	Steady state efficiency
29.	FootPrint	567.0 mm^2	System Information	Total Foot Print Area of BOM components
30.	Frequency	300.0 kHz	System Information	Switching frequency
31.	Gain Marg	12.337 db	System Information	Bode Plot Gain Margin
32.	Mode	DCM	System Information	Conduction Mode
33.	Phase Marg	48.499 deg	System Information	Bode Plot Phase Margin
34.	Phase Shift	43.129 deg	System Information	Bode Plot Phase Shift
35.	Total BOM	$4.75	System Information	Total BOM Cost
36.	Vin p-p	332.274 mV	System Information	Peak-to-peak input voltage
37.	Vout p-p	91.229 mV	System Information	Peak-to-peak output ripple voltage

Design Inputs

Name	Value	Description
Iout	1.0	Maximum Output Current
VinMax	32.0	Maximum input voltage
VinMin	24.0	Minimum input voltage
Vout	-12.0	Output Voltage
base_pn	LM5005	Base Product Number
source	DC	Input Source Type
Ta	30.0	Ambient temperature

WEBENCH® Assembly

Component Testing

Some published data on components in datasheets such as Capacitor ESR and Inductor DC resistance is based on conservative values that will guarantee that the components always exceed the specification. For design purposes it is usually better to work with typical values. Since this data is not always available it is a good practice to measure the Capacitance and ESR values of Cin and Cout, and the inductance and DC resistance of L1 before assembly of the board. Any large discrepancies in values should be electrically simulated in WEBENCH to check for instabilities and thermally simulated in WebTHERM to make sure critical temperatures are not exceeded.

Soldering Component to Board

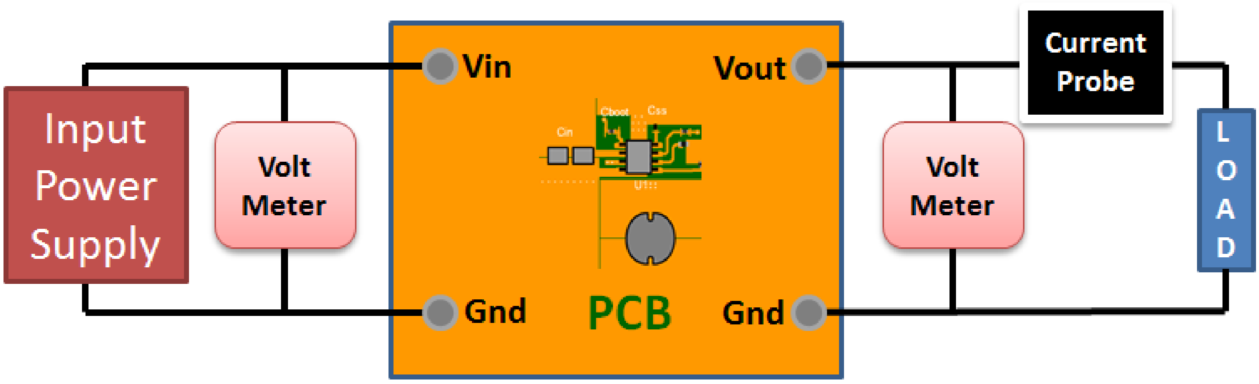
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. To solder the tab town to the board place the iron down on the board while resting against the tab, heating both surfaces simultaneously. Apply light pressure to the top of the plastic case until the solder flows around the part and the part is flush with the PCB. If the solder is not flowing around the board you may need a higher wattage iron (generally 25W to 30W is enough).

Initial Startup of Circuit

It is best to initially power up the board by setting the input supply voltage to the lowest operating input voltage 24.0V and set the input supply's current limit to zero. With the input supply off connect up the input supply to Vin and GND. Connect a digital volt meter and a load if needed to set the minimum Iout of the design from Vout and GND. Turn on the input supply and slowly turn up the current limit on the input supply. If the voltage starts to rise on the input supply continue increasing the input supply current limit while watching the output voltage. If the current increases on the input supply, but the voltage remains near zero, then there may be a short or a component misplaced on the board. Power down the board and visually inspect for solder bridges and recheck the diode and capacitor polarities. Once the power supply circuit is operational then more extensive testing may include full load testing, transient load and line tests to compare with simulation results.

Load Testing

The setup is the same as the initial startup, except that an additional digital voltmeter is connected between Vin and GND, a load is connected between Vout and GND and a current meter is connected in series between Vout and the load. The load must be able to handle at least rated output power + 50% (7.5 watts for this design). Ideally the load is supplied in the form of a variable load test unit. It can also be done in the form of suitably large power resistors. When using an oscilloscope to measure waveforms on the prototype board, the ground leads of the oscilloscope probes should be as short as possible and the area of the loop formed by the ground lead should be kept to a minimum. This will help reduce ground lead inductance and eliminate EMI noise that is not actually present in the circuit.



Design Assistance

1. Master key : 4BB4D4A5A0543D66[v1]

2. **LM5005** Product Folder : http://www.ti.com/product/LM5005 : contains the data sheet and other resources.