ICRON TECHNOLOGIES CORPORATION'S

PC-ON-TV POWER SUPPLY ARCHITECTURE

Icron Technologies Corporation

Date

ABSTRACT

Icron Technologies Corporation in Burnaby, BC, is developing a consumer product that will enable users to access their computer at their television. The aim is to be able to view PC content, such as downloaded movies and various internet applications in high definition on a large screen. In this regard, the PC-on-TV product is similar to AppleTV, and several others video extensions to the television already available in the market. However, with PC-on-TV there are no application restrictions, as the interface is transparent and the user has access to literally the entire computer and internet. There is also the important addition of USB (Universal Serial Bus) extension, allowing the user to connect devices such as a wireless keyboard and mouse, webcam, and USB storage within the vicinity of the television. The modes of connectivity between the computer and the television include fiber cable, Ethernet and 802.11 wireless.

Upon the completion of signal processing circuitry design, circuit boards for boxes on both the PC and TV side are in need of a power supply architecture to fulfill the necessary current requirements at each voltage level. An initial assessment yielded the need for switching power supplies capable of handling a 5V input and producing an output of 2A, and also those tolerant of a 12V input and capable of 3A. Units in the latter group with higher current capabilities have a greater influence on total system price, and thus are the ones assessed in this report.

The three most price-worthy power supplies – MAX15041, MP2307 and ST1S10 – are evaluated for total cost per voltage rail, current load testing, efficiency, input voltage testing, ripple current and transient response. The results are also summarized in an easy-to-reference appendix for quick comparison.

CONTENTS

LIST OF FIGURES AND TABLES

List of Figures

List of Tables

LIST OF ABBREVIATIONS

CODEC	Coder-decoder
ESR	Effective series resistance
LDO	Low drop-out regulator
MOSFET	Metal-oxide semiconductor field effect transistor
PGOOD	Power good
USB	Universal Serial Bus

1. INTRODUCTION

As provisions for unforeseen cases, the prototype boards used for development in the laboratory utilized expensive power supplies with performance capabilities far exceeding requirements of the boards. In cost reduction effort, it was necessary to develop a new power architecture which maximizes the potential and efficiency of the power supplies and lowers overall system cost.

The main considerations were that lower voltage tolerant chips (i.e. those allowing a lower input voltage) are cheaper, and a lower voltage drop from input to output yields better efficiency. Therefore it sometimes makes sense to develop multiple–stage systems, drawing the input of some units from the outputs of others instead of just using the wall adaptor as the universal input. However, linking power supplies as mentioned draws more current through the ones with higher voltage inputs, and higher current capabilities also raise the price of switchers.

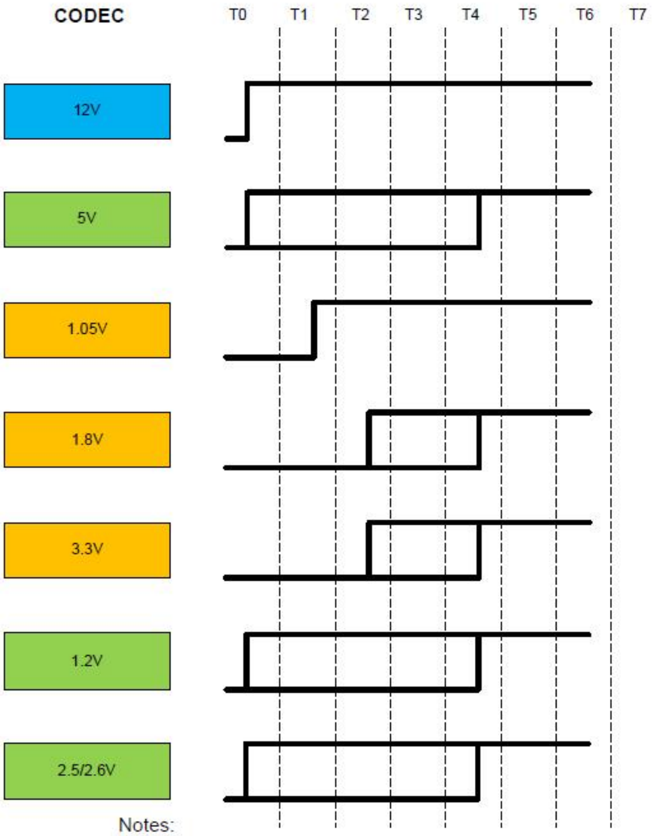
The peripheral components of the power supplies must also be taken into account. It is common for cheap power supplies to require many or costly capacitors and inductors, and sometimes external MOSFETs or Schottky diodes. A component-by-component cost analysis was performed on every solution considered, and used in the final decision making process. Another factor that can lower design cost is a simpler schematic implementation, since it also implies a quicker design period. Overall, the output voltage quality (cleanliness and transient response of the power supply's output) is weighed the most, succeeded by the price and efficiency.

From the bill of materials of the PC-on-TV project and the required maximum currents specified on the components' datasheets, the power requirements were calculated and formulated into Table 1.

Voltage	Current Required (mA)	
	PC Side	TV Side
1.05	800	800
1.2	370	370
1.8	850	850
2.5	70	100
3.3	1350	1500
5	350	2500

Table 1: Power requirements for Icron's PC-on-TV circuit boards.

There is only one constraint to how different voltages may be derived from one another. The Codec responsible for video signal processing and compression, uses three voltage levels – 1.05V, 1.8V and 3.3V. It requires the 1.05V rail to enable before or simultaneously with the other two. Figure 1 visually captures this requirement in a timing diagram.



Notes:

1. The time delay from T1 to T2 should be at least 500us.
2. 1.05V must come up before 1.8V and 3.3V.
3. The windows show that the power rails can come up any time within the window.
4. Vin to the system is 12V.

Figure 1: Timing requirements for the video Codec.

2. CHOSEN ARCHITECTURE

The power supply architectures with the lowest system cost were determined to be ones utilizing the maximum number of switching power supplies with low input voltages. By using lower voltage silicon, the user reduces costs on the switcher itself and the input capacitors.

On the TV side, this means using one power supply to bring 12V from the power adaptor down to 5V for the remaining switchers to use. In this case, the 12V → 5V power supply would have to support 4A.

However, from the price quotes received from distributor representatives, there is a significant price drop for modules with a current output of 3A. For this reason, we settle for two power supplies with inputs rated at 12V+ capable of producing 3A, and use these to supply 5V input switchers for all the other power rails (see Figure 1). This also happens to be the more efficient method, because the 5V power rail now provides a lower current. LDOs are used for rails with low current output requirements.

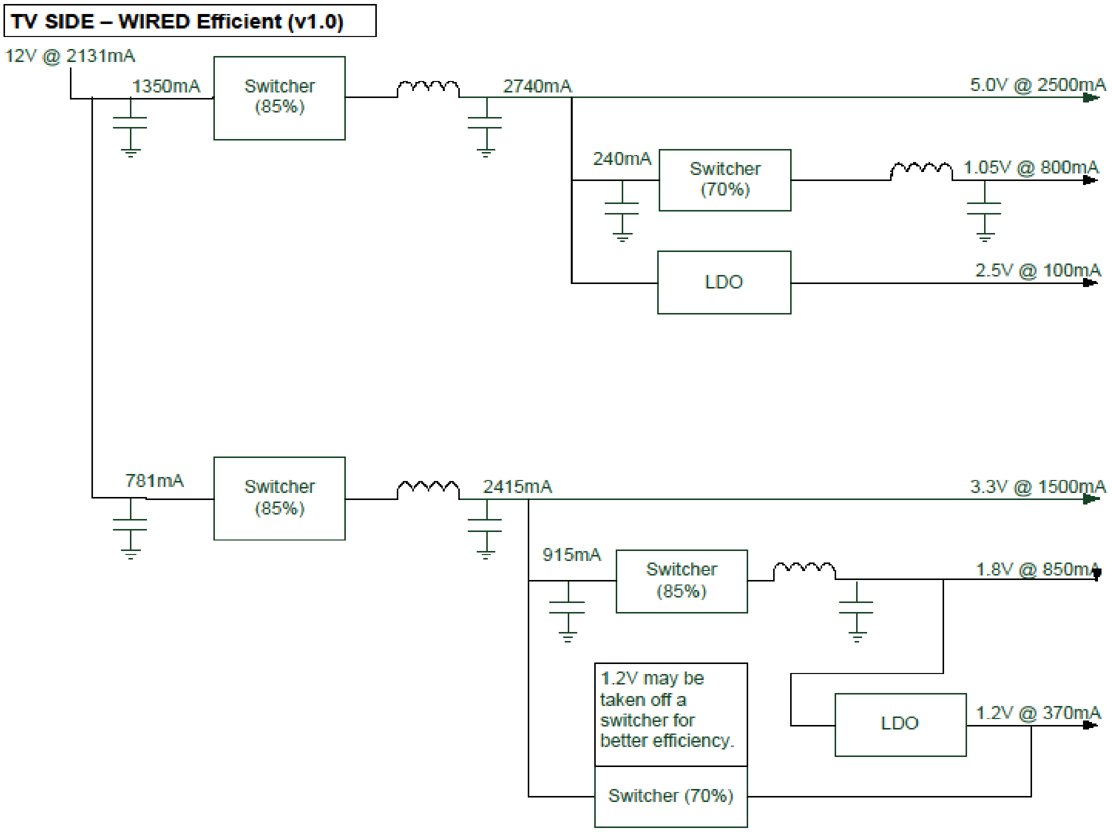


Figure 2: TV side architecture block diagram.

This layout also satisfies the timing requirements laid out in Figure 1, if the entire 3.3V switcher is enabled only after the 1.05V rail comes up. The architecture on the PC side is much simpler, since the voltage supplied by the wall adaptor is already 5V. Here, only low input voltage switchers and LDOs are used. It must be noted, that again due to timing requirements 1.05V cannot be derived from either 3.3V or 1.8V.

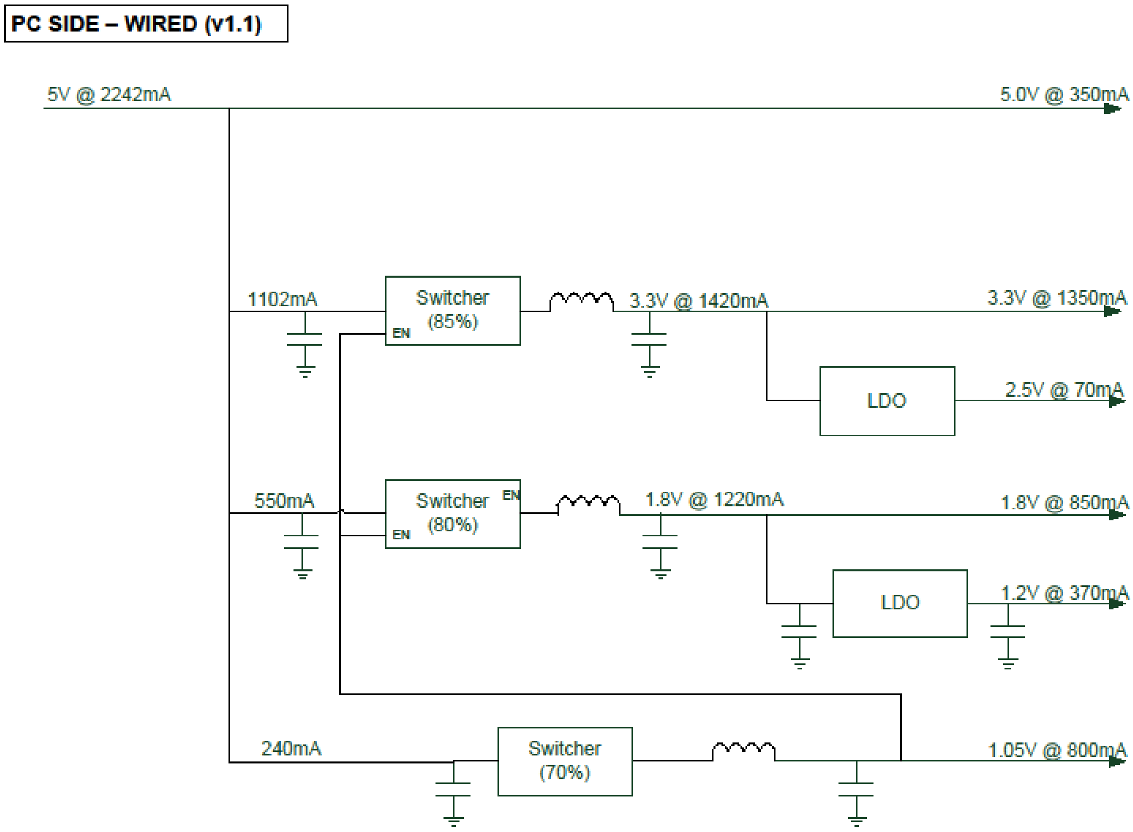


Figure 3: PC side architecture block diagram.

Based on the aforementioned architectures, it is possible to divide the switching power supply analysis into two parts – low input voltage switchers with lower output current capabilities (<6V in, 2A), and higher input voltage switchers capable of higher output currents (>12V in, 3A). The following sections cover only the comparison of power supplies with higher current capabilities because they contribute significantly more to overall system cost. Hence the focus will only be on the TV side of the project.

3. TEST RESULTS FOR 12V INPUT, 3A SWITCHING POWER SUPPLIES

Three higher voltage input power supplies were selected for price, and tested. The price comparison of all the regulators will not be shown here comprehensively due to its length; however a cost analysis for the power supplies evaluated for performance is included. From Maxim, Monolithic Power Supply, and ST Microelectronics, the chips considered were MAX15041, MP2307 and ST1S10, respectively. Each power supply was analyzed for efficiency, output voltage variation from load and input voltage, ripple voltage at various loads, and the transient response. Appendix A includes a visual comparison of the efficiencies and load testing of each of the chips.

3.1. MAX15041 Analysis

3.1.1. Chip Overview and Cost Breakdown

The MAX15041 power supply is a step-down buck regulator with integrated FETs and an implementation schematic of average complexity. It supports input voltages up to 28V and output currents up to 3A. To determine which peripheral components are appropriate for the device, the generic input and output capacitor and inductor equations were referenced from the MAX15041 datasheet[1]. The recommended inductor value was deduced from Equation 1.

$$L = V_{out} * (V_{in} - V_{out}) / (f_{SW} * \Delta I_L * V_{in}) \qquad (1)$$

ΔI_L is the maximum change in current load, or the inductor ripple current, which is recommended to be set to 30% of the expected maximum current drawn from the switcher. However in our case we expect changes of up to 1.2A when the boards are booting.

For use on a 5V rail, V_{out} is 5V, V_{in} is 12V, f_{SW} is 350kHz[1], and ΔI_L is 1400mA. Thus, we get:

$$L = 5V * (12V-5V) / (350e3Hz * 1.2A * 12V) = 6.94\mu H$$

Thus a value of 6.8µH was chosen for the MAX15041. The input and output capacitor values were deduced from Equations 2 and 3, respectively. The allowed ripple currents were 100mV on the input and 50mV on the output, since neither the 3.3V or 5V are sensitive rails.

$$C_{in} = I_{LOAD} * V_{out} / (f_{SW} * \Delta V_{in\_ripple} * V_{in}) \qquad (2)$$

$$\Delta V_{out} = V_{out} * (V_{in} - V_{out}) * [R_{ESR\_Cout} + 1/(8 * f_{SW} * C_{out})] / (f_{SW} * L * V_{in}) \qquad (3)$$

For capacitors with low ESR, such as the ceramic capacitors used in this design, the voltage ripple due to ESR is negligible, so that $R_{ESR\_Cout} << 1/(8* f_{SW} * C_{out})$. Equation 3 then simplifies to:

$$C_{out} = V_{out} * (V_{in} - V_{out}) / (8 * f_{SW}^2 * L * \Delta V_{out} * V_{in}) \qquad (4)$$

In our case,

$$C_{in} = 1.4A * 5V / (350e3Hz * 0.09V * 12V) = 18.5\mu F$$

$$C_{out} = 5V * (12V-5V) / (8 * 350e3Hz^2 * 6.8e\text{-}6H * 0.05V * 12V) = 8.75\mu F$$

Based on the values calculated, 20µF capacitors were picked for C_{in} and 10µF for C_{out}. A similar procedure for the 3.3V rail yields:

$$L = 3.3V * (12V-3.3V) / (350e3Hz * 1.2A * 12V) = 5.70\mu H$$

$$C_{in} = 1.4A * 3.3V / (350e3Hz * 0.09V * 12V) = 12.2\mu F$$

$$C_{out} = 3.3V * (12V-3.3V) / (8 * 350e3Hz^2 * 6.8e\text{-}6H * 0.05V * 12V) = 7.18\mu F$$

MAX15041 also requires a low-current Schottky diode. Using the component price matrix provided by a passive component distributor in Table 2, the total peripheral component cost is $0.40 per rail ($0.25 for the 5A inductor, $0.10 for a 20µF, 16V ceramic capacitor, $0.02 for a 10uF, 6.3V capacitor and $0.03 for a low-current Schottky duide). The chip itself is quoted at $0.95, so the complete “price per rail” using this power supply is estimated to be $1.35. All other components, like resistors and small capacitors, have a negligible price contribution.

Inductors	Value	Current = 2A	Current = 3A	Current = 5A
	1.5uH	$ 0.08	$ 0.12	$ 0.16
	2.2uH	$ 0.10	$ 0.15	$ 0.18
	3.3uH	$ 0.10	$ 0.17	$ 0.20
	4.7uH	$ 0.15	$ 0.19	$ 0.22
	6.8uH	$ 0.18	$ 0.21	$ 0.25
	10uH	$ 0.20	$ 0.24	$ 0.28
	15uH	$ 0.23	$ 0.28	$ 0.33

Capacitors	Value	V = 25	V = 16	V = 6.3
	4.7uF	$ 0.05	$ 0.03	$ 0.01
	10uF	$ 0.10	$ 0.05	$ 0.02
	22uF	$ 0.17	$ 0.10	$ 0.05
	33uF	$ 0.25	$ 0.15	$ 0.08
	47uF	$ 0.30	$ 0.20	$ 0.10
	68uF	$ 0.40	$ 0.30	$ 0.15
	100uF	$ 0.60	$ 0.45	$ 0.25

Schottky	Current	Price
	I < 4A	$ 0.03
	I > 4A	$ 0.06

Table 2: Peripheral component price matrix.

Table 3 summarizes the capabilities of the chip, and the peripheral component values which were used for analysis in the laboratory. Note that tests were performed at a 3.3V output.

V_{in}	4.5 ~ 28	V
V_{out}	0.6 ~ 24	V
Max Current	3	A
Switching Frequency	350	kHz
C_{in}	20	uF
C_{out}	10	uF
Inductor	6.8	uH
Power Good	Yes	
Enable	Yes	
Price per Rail	$ 1.35	

Table 3: MAX15041 chip overview.

3.1.2. Efficiency

Efficiency was measured using 0.1Ω (1%) power resistors wired in series with the V_{in} and V_{out} pins of the power supply (see Figure 4).

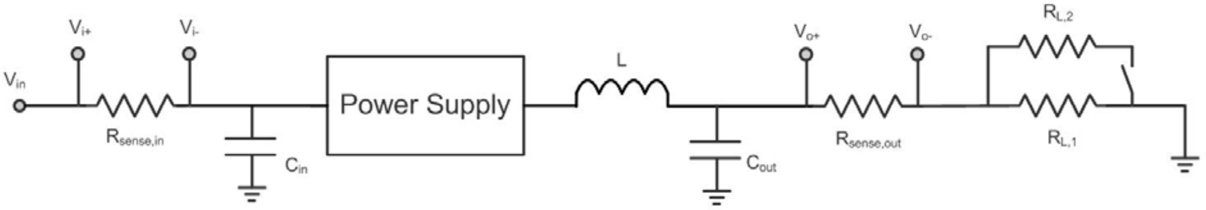


Figure 4: Efficiency measurement setup.

Using a potentiometer for $R_{L,1}$, it is possible to extract different currents from the power supply. The voltages across both of the sense resistors were recorded in Table 4, and input and output currents calculated from it. Efficiency was taken to be the ratio of input and output powers (see Equation 5).

$$\eta = (V_{out} * I_{out}) / (V_{in} * I_{in}) \tag{5}$$

V_in [V]	V_out [V]	R_in,sense [Ω]	R_out,sense [Ω]	V_in,sense [mV]	V_out,sense [mV]	I_in [A]	I_out [A]	Eff
12.0	3.372	0.1	0.1	0.0	0.0	0.000	0.000	-
12.0	3.371	0.1	0.1	11.2	30.6	0.112	0.306	77%
12.1	3.361	0.1	0.1	18.2	59.2	0.182	0.592	90%
12.1	3.337	0.1	0.1	24.2	81.6	0.242	0.816	93%
12.1	3.359	0.1	0.1	29.7	99.7	0.297	0.997	93%
12.1	3.36	0.1	0.1	36.7	122.7	0.367	1.227	93%
12.0	3.365	0.1	0.1	46.2	147.8	0.462	1.478	90%
12.0	3.368	0.1	0.1	64.5	201.1	0.645	2.011	87%
12.0	3.347	0.1	0.1	75.7	234.3	0.757	2.343	86%
12.0	3.348	0.1	0.1	88.6	265.6	0.886	2.656	84%
12.0	3.337	0.1	0.1	101.1	304.3	1.011	3.043	84%
12.0	3.332	0.1	0.1	124.3	341.4	1.243	3.414	77%
12.0	5.110	0.1	0.1	108.0	223.8	1.080	2.238	88%

Table 4: Efficiency calculations for MAX15041 at an output of 3.3V.

3.1.3. Load Testing and Input Voltage Testing

Load testing results can be seen in Table 4. Throughout the operating range of 0 to 2.7A, the output voltage dropped only 35mV. This is a tolerable result, since no components in Icron's PC-on-TV design requiring 3.3 or 5V have such tight voltage requirements.

MAX15041 was also stable under a varying input voltage, showing a maximum output swing of 9 mV from the nominal value – the value with 12V as the input voltage (see Table 5). Under real circumstances, the wall adaptor would provide a V_{in} with much less deviation from 12V – the realistic minimum being 10.8, and the maximum 13.2V. The test performed goes beyond this range not only to cover some extreme cases, but also some human error.

I_out [A]	V_in [V]	V_out [V]
2.656	12.0	3.349
2.656	16.0	3.358
2.656	9.0	3.343
1.478	9.0	3.359
1.478	16.0	3.365
1.478	12.0	3.369

Table 5: Input voltage testing results for MAX15041.

3.1.4. Ripple Voltage

The ripple voltages of the MAX15041 switching power supply, recorded at 0.3A, 1.5A and 2.7A loads, are shown in Figures 5-7 on the following page. The maximum ripple voltage for the chip with the selected components is only 63mV peak-to-peak, and with spikes of roughly 160mV.

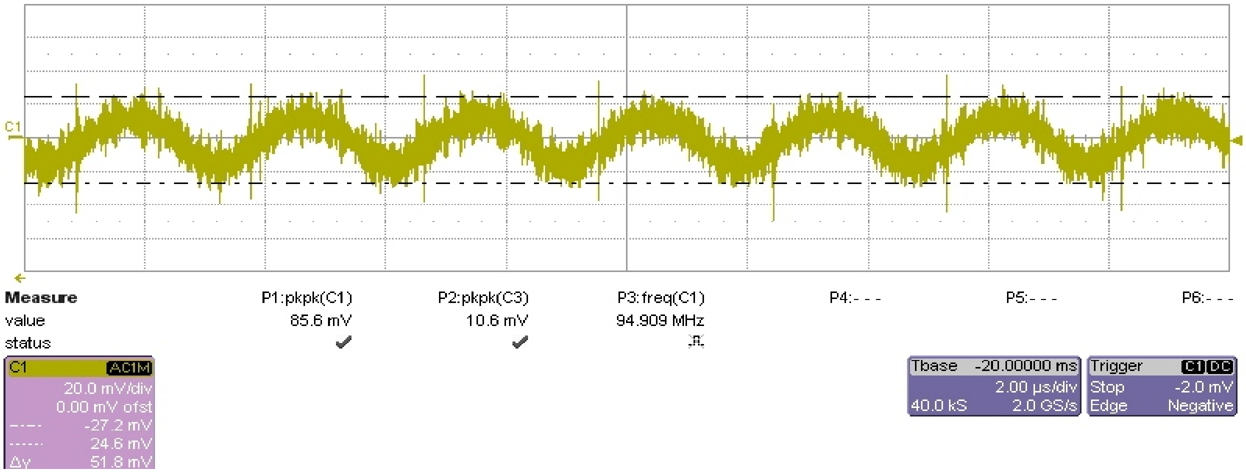


Figure 5: MAX15041 ripple voltage with a 300mA load.

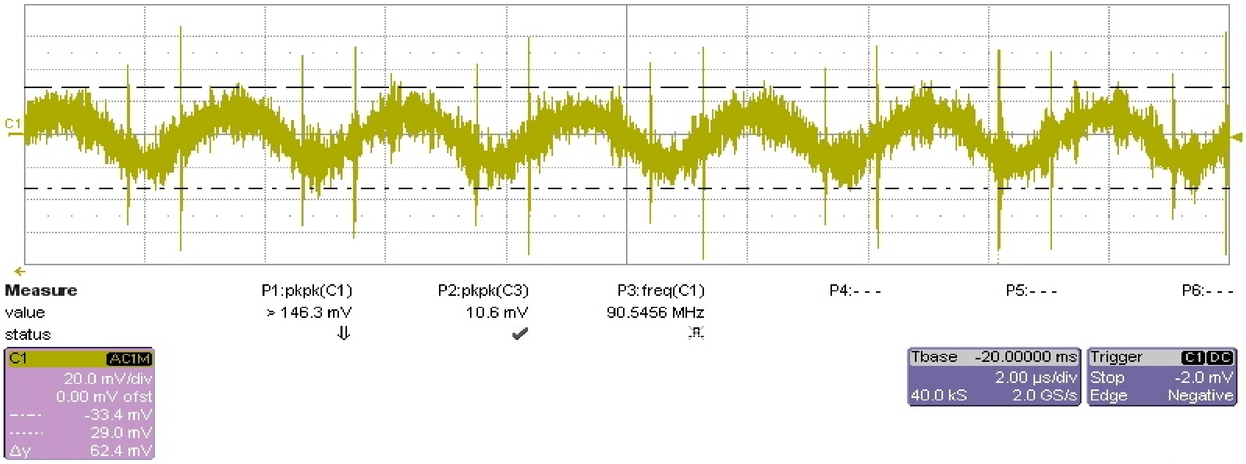


Figure 6: MAX15041 ripple voltage with a 1.5A load.

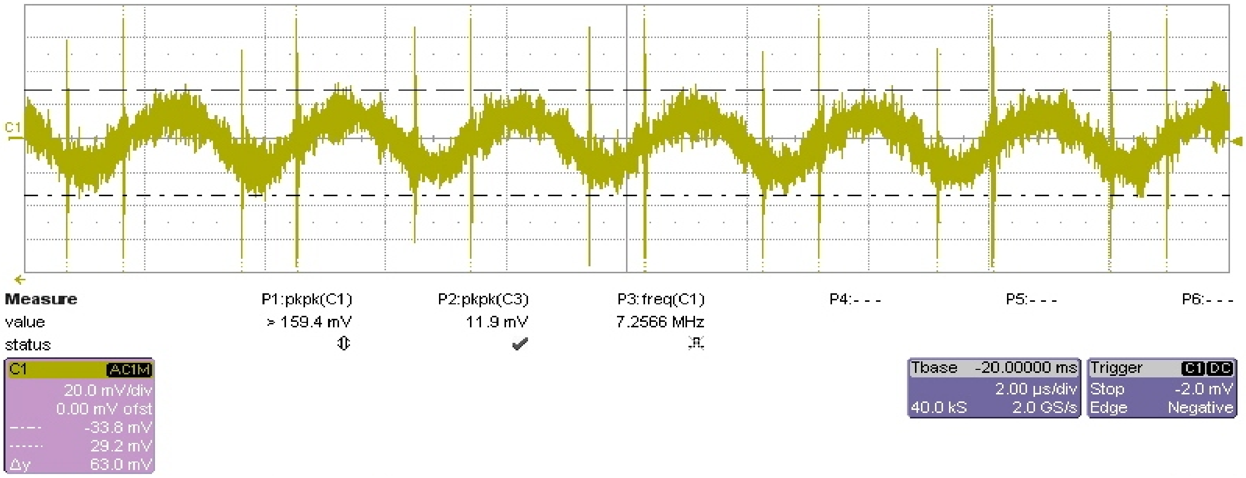
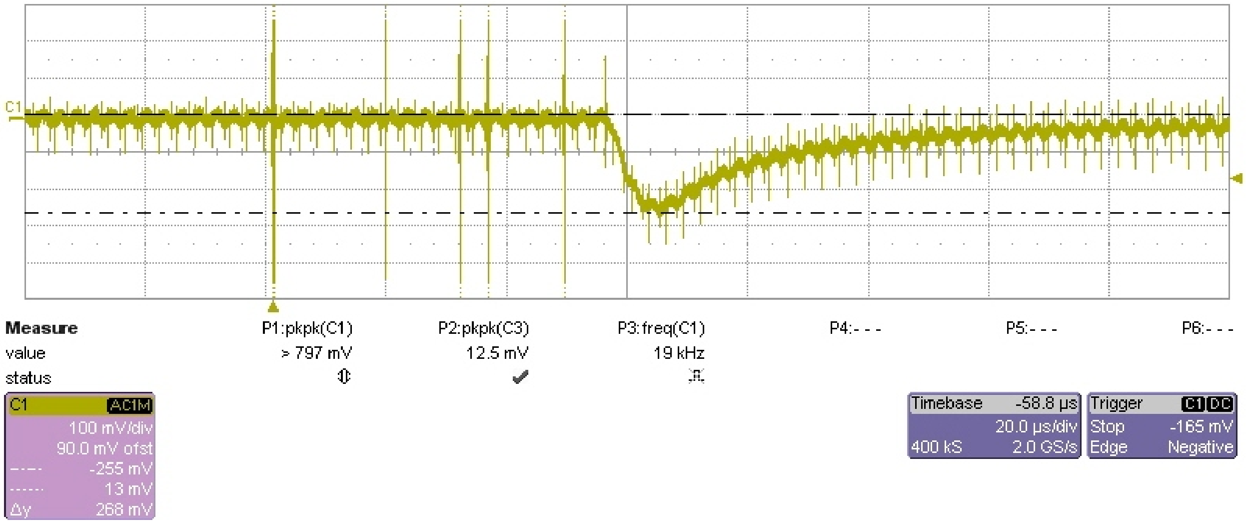


Figure 7: MAX15041 ripple voltage with a 2.7A load.

3.1.5. Transient Response

While already producing a current of 1.5A, an additional load of 1.2A was applied to the power supply. $R_{L,2}$ in the setup depicted in Figure 4 is used to apply the additional load. The output voltage drop – about 270mV, recovers with a time constant τ of approximately 30µs. The results are presented in Figure 8.



Measure	P1:pkpk(C1)	P2:pkpk(C3)	P3:freq(C1)	P4:- - -	P5:- - -	P6:- - -
value	> 797 mV	12.5 mV	19 kHz			
status		✓				

C1 AC1M
100 mV/div
90.0 mV ofst
-255 mV
13 mV
Δy 268 mV

Timebase -58.8 µs
20.0 µs/div
400 kS 2.0 GS/s

Trigger C1 DC
Stop -165 mV
Edge Negative

Figure 8: MAX15041 transient response, from 1.5A to a 2.7A load.

3.2. MP2307 Analysis

3.2.1. Chip Overview and Cost Breakdown

The MP2307 power supply is a step-down buck regulator with integrated MOSFETs and a simple implementation schematic. It supports continuous output currents up to 3A, and peak currents up to 4A. Following the procedure developed for the MAX15041 power supply, and utilizing Equations 1, 2 and 4, it is possible to derive recommended values for components around the MP2307 for both 5V and 3.3V outputs.

L_{5V} = 5V * (12V-5V) / (340e3Hz * 1.2A * 12V) = 7.15µH

$C_{in,5V}$ = 1.4A * 5V / (340e3Hz *0.09V * 12V) = 19.06µF

$C_{out,5V}$ = 5V * (12V-5V)/ (8* 340e3Hz^2 * 10e-6H * 0.05V * 12V) = 6.31µF

L_{3V3} = 3.3V * (12V-3.3V) / (340e3Hz * 1.4A * 12V) = 5.33µH

$C_{in,3V3}$ = 1.4A * 3.3V / (340e3Hz *0.09V * 12V) = 12.6µF

$C_{out,3V3}$ = 3.3V * (12V-3.3V)/ (8* 340e3Hz^2 * 6.8-6H * 0.05V * 12V) = 7.18µF

Despite the calculations, Monolithic Power Supply recommends a minimum capacitance of 22µF on the output, and even two 22µF for applications where the output voltage is less than 2.5V. Hence the values chosen were 10µH and 6.8µH for inductors, 20µF for input capacitors and 22µF for output capacitors. Using the price matrix, the total peripheral cost per rail is:

[\$0.28+\$0.25 (L) + 2x\$0.10 (C_{in}) + 2x\$0.05 (C_{out})]/2 = \$0.42

Including the silicon cost of \$0.85, the complete cost of a voltage rail using a MP2307 regulator is \$1.27. However, due to the lack of a "power good" pin, there is a slight (~\$0.03) incurred cost of some transistor logic to derive the PGOOD signal. Table 6 shows the capabilities of the chip, and the peripheral component values with which it was analyzed in the laboratory.

V_{in}	4.7 ~ 23	V
V_{out}	0.9 ~ 20	V
Max Current	3	A
Switching Frequency	340	kHz
C_{in}	20	uF
C_{out}	22	uF
Inductor	6.8	uH
Power Good	No	
Enable	Yes	
Price per Rail	\$ 1.27	

Table 6: MP2307 chip overview.

3.2.2. Efficiency

Efficiency was measured using 0.1Ω (1%) power resistors wired in series to the V_{in} and V_{out} pins of the power supply, as in Figure 4. The voltages across both of them were recorded in Table 7 and input and output currents calculated from them. Efficiency was again taken to be the ratio of input and output powers. It wasn't recorded for a 5V output because a 3.3V output comparison is more crucial – the efficiency of a power supply with a higher voltage drop will always be lower. Hence only the worst-case scenario was taken into account.

V_in [V]	V_out [V]	R_in,sense [Ω]	R_out,sense [Ω]	V_in,sense [mV]	V_out,sense [mV]	I_in [A]	I_out [A]	Eff
12.0	3.416	0.1	0.1	0.0	0.0	0.000	0.000	-
12.0	3.413	0.1	0.1	10.4	31.3	0.104	0.313	86%
11.2	3.416	0.1	0.1	49.3	140.2	0.493	1.402	87%
11.2	3.273	0.1	0.1	96.5	254.1	0.965	2.541	77%
12.1	2.632	0.1	0.1	79.2	296.0	0.792	2.960	81%

Table 7: Efficiency calculations for MP2307 at an output of 3.3V.

3.2.3. Load Testing and Input Voltage Testing

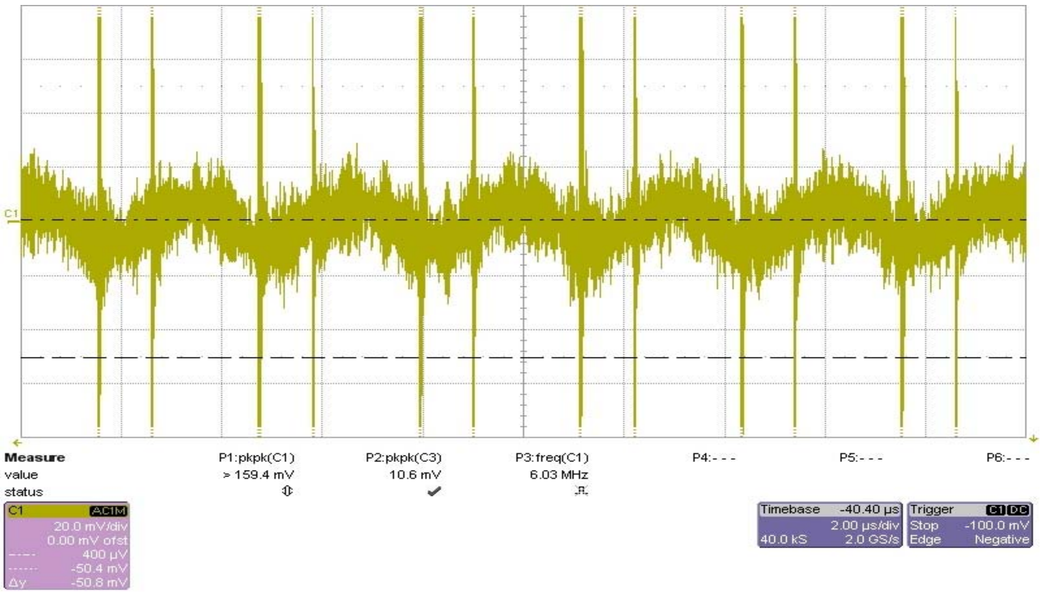
Load testing results can be seen in Table 7. Throughout the operating range of 0 to 2.5A, the output voltage dropped by 143mV. At even higher loads, the output drops substantially, and stops being stable. At a load of around 2.9A, the output voltage reduces by more than half a volt. This performance is very poor compared to that of the MAX15041 (see Appendix A). MP2307 was also less stable than the MAX15041 under a varying input voltage, showing a maximum output swing of 42mV from the nominal value at a 3A load (see Table 8). At lower currents, the output was much more stable.

I_out [A]	V_in [V]	V_out [V]
1.402	9.0	3.415
1.402	12.0	3.415
1.402	16.0	3.416
2.960	9.0	3.175
2.960	12.0	3.133
2.960	16.0	3.150

Table 8: Input voltage testing results for MP2307.

3.2.4. Ripple Voltage

The ripple voltages of the MP2307 switching power supply, recorded at 1.4A and 3A loads, are shown below in Figure 9 and Figure 10. The maximum ripple voltage is approximately 105mV, with spikes exceeding 0.5V, which is a significantly poorer result than the MAX15041.



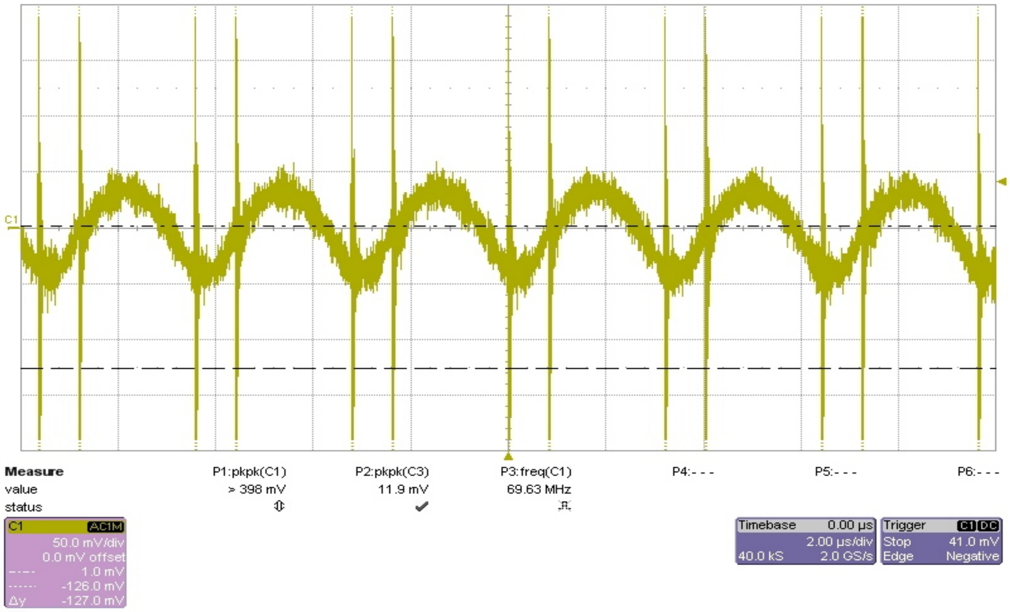
Measure	P1:pkpk(C1)	P2:pkpk(C3)	P3:freq(C1)	P4:- - -	P5:- - -	P6:- - -
value	> 159.4 mV	10.6 mV	6.03 MHz			
status		✓				

C1 AC1M
20.0 mV/div
0.00 mV ofst
400 µV
-50.4 mV
Δy -50.8 mV

Timebase -40.40 µs
2.00 µs/div
40.0 kS 2.0 GS/s

Trigger C1 DC
Stop -100.0 mV
Edge Negative

Figure 9: MP2307 ripple voltage with a 1.4A load.



Measure	P1:pkpk(C1)	P2:pkpk(C3)	P3:freq(C1)	P4:- - -	P5:- - -	P6:- - -
value	> 398 mV	11.9 mV	69.63 MHz			
status		✓				

C1 AC1M
50.0 mV/div
0.0 mV offset
1.0 mV
-126.0 mV
Δy -127.0 mV

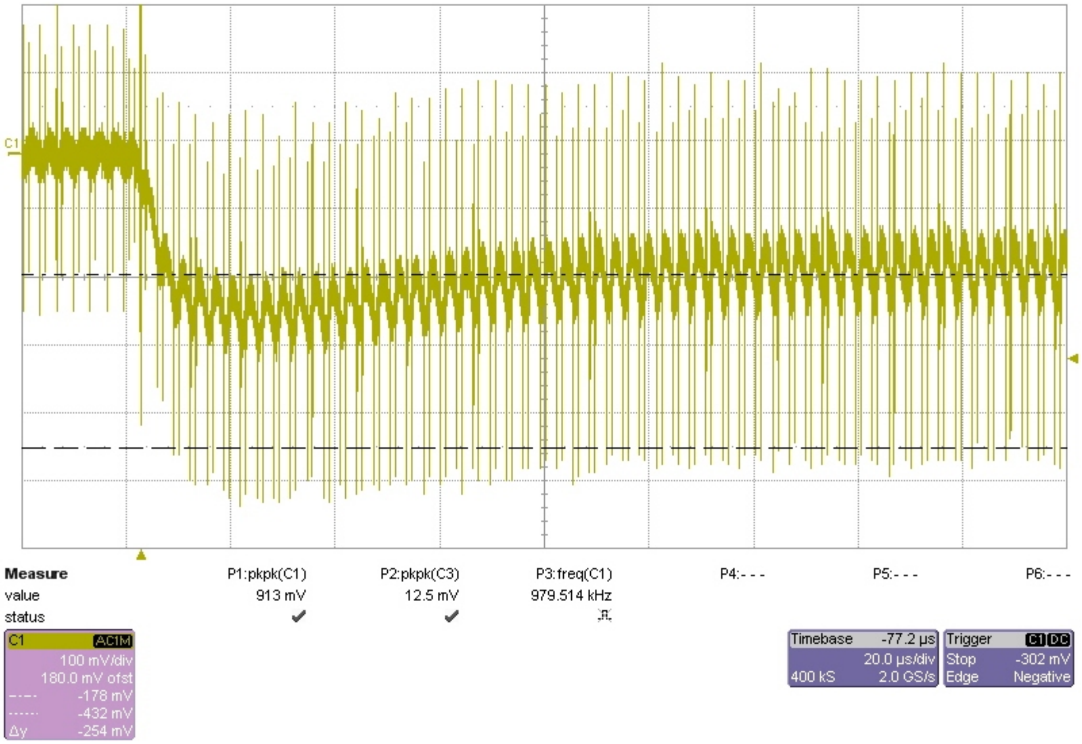
Timebase 0.00 µs
2.00 µs/div
40.0 kS 2.0 GS/s

Trigger C1 DC
Stop 41.0 mV
Edge Negative

Figure 10: MP2307 ripple voltage with a 3.0A load.

3.2.5. Transient Response

While already producing a current of 1.4A, an additional load of 1.6A was applied to the power supply. The output voltage drop – about 260mV, recovers with a time constant τ ~ 50µs. The results are presented in Figure 8. However, it must be noted that the output voltage never recovers to a reasonable or usable level under such a load; it remains almost 200mV lower than the voltage value at a load lighter by 300mA. This corresponds with the findings in Section 3.2.3.



Measure	P1:pkpk(C1)	P2:pkpk(C3)	P3:freq(C1)	P4:- - -	P5:- - -	P6:- - -
value	913 mV	12.5 mV	979.514 kHz			
status	✓	✓				

C1 AC1M
100 mV/div
180.0 mV ofst
-·-·- -178 mV
------ -432 mV
Δy -254 mV

Timebase -77.2 µs
20.0 µs/div
400 kS 2.0 GS/s

Trigger C1 DC
Stop -302 mV
Edge Negative

Figure 11: MP2307 transient response, from 1.5A to a 2.9A load.

3.3. ST1S10 Analysis

3.3.1. Chip Overview and Cost Breakdown

The ST1S10 power supply is a step-down buck regulator with integrated FETs and a simple implementation schematic. It supports continuous output currents up to 3A. Utilizing Equations 1 and 2, its peripheral component values are calculated below.

L_{5V} = 5V * (12V-5V) / (900e3Hz * 1.2A * 12V) = 2.7µH

$C_{in,5V}$ = 1.4A * 5V / (900e3Hz *0.09V * 12V) = 7.20µF

L_{3V3} = 3.3V * (12V-3.3V) / (900e3Hz * 1.4A * 12V) = 2.22µH

$C_{in,3V3}$ = 1.4A * 3.3V / (900e3Hz *0.09V * 12V) = 4.75µF

Based on the calculations above, 3.3µH was the chosen inductor value, and 4.7µF for the input capacitors. The output capacitors are recommended to be set to 22µF because the power supply is designed to work most efficiently when operating "with a natural output LC frequency provided by a 3.3µH inductor and a 22µF capacitor"[2]. The cost for implementing the ST1S10 regulator is thus:

$0.20 (L) +$0.03 (C_{in}) + $0.05 ($C_{out}$) + $0.93 (quoted silicon price) = $1.21

However, like the MP2307, this power supply lacks the PGOOD pin, and will need some external logic for it. Table 9 summarizes the capabilities of the chip, and the components with which it was analyzed.

V_{in}	2.5 ~ 18	V
V_{out}	0.8 ~ 18	V
Max Current	3	A
Switching Frequency	900	kHz
C_{in}	4.7	uF
C_{out}	22	uF
Inductor	3.3	uH
Power Good	No	
Enable	Yes	
Price per Rail	$ 1.21	

Table 9: ST1S10 chip overview.

3.3.2. Efficiency

Efficiency was measured using 0.1Ω (1%) power resistors wired in series to the V_{in} and V_{out} pins of the power supply (see Figure 4). The voltages across both of them were recorded in Table 10, and input and output currents calculated from them. Efficiency was again calculated with Equation 5. The resulting efficiencies are good for a 3A power supply, but slightly poorer than MAX15041's (see Appendix A).

V_in [V]	V_out [V]	R_in,sense [Ω]	R_out,sense [Ω]	V_in,sense [mV]	V_out,sense [mV]	I_in [A]	I_out [A]	Eff
12.2	3.259	0.1	0.1	0.0	0.0	0.000	0.000	-
12.2	3.258	0.1	0.1	9.3	29.3	0.093	0.293	84%
12.1	3.258	0.1	0.1	16.3	53.4	0.163	0.534	88%
12.1	3.257	0.1	0.1	20.9	69.3	0.209	0.693	89%
12.1	3.259	0.1	0.1	25.0	83.0	0.250	0.830	89%
12.1	3.258	0.1	0.1	30.4	100.8	0.304	1.008	89%
12.1	3.259	0.1	0.1	38.4	126.8	0.384	1.268	89%
12.1	3.258	0.1	0.1	45.5	149.3	0.455	1.493	88%
12.1	3.260	0.1	0.1	61.8	197.1	0.618	1.971	86%
12.1	3.261	0.1	0.1	67.3	214.1	0.673	2.141	86%
12.1	3.263	0.1	0.1	76.2	244.7	0.762	2.447	87%
12.0	3.265	0.1	0.1	91.5	275.3	0.915	2.753	82%
12.0	3.262	0.1	0.1	102.6	305.3	1.026	3.053	81%
12.0	3.260	0.1	0.1	121.8	345.3	1.218	3.453	77%

Table 10: Efficiency calculations for ST1S10 at an output of 3.3V.

3.3.3. Load Testing and Input Voltage Testing

Load testing results can be seen in Table 10. Throughout the operating range of 0 to 3.4A, the output voltage is very stable, varying only by only about 6mV. This performance is even better than that of the MAX15041, and far superior to MP2307.

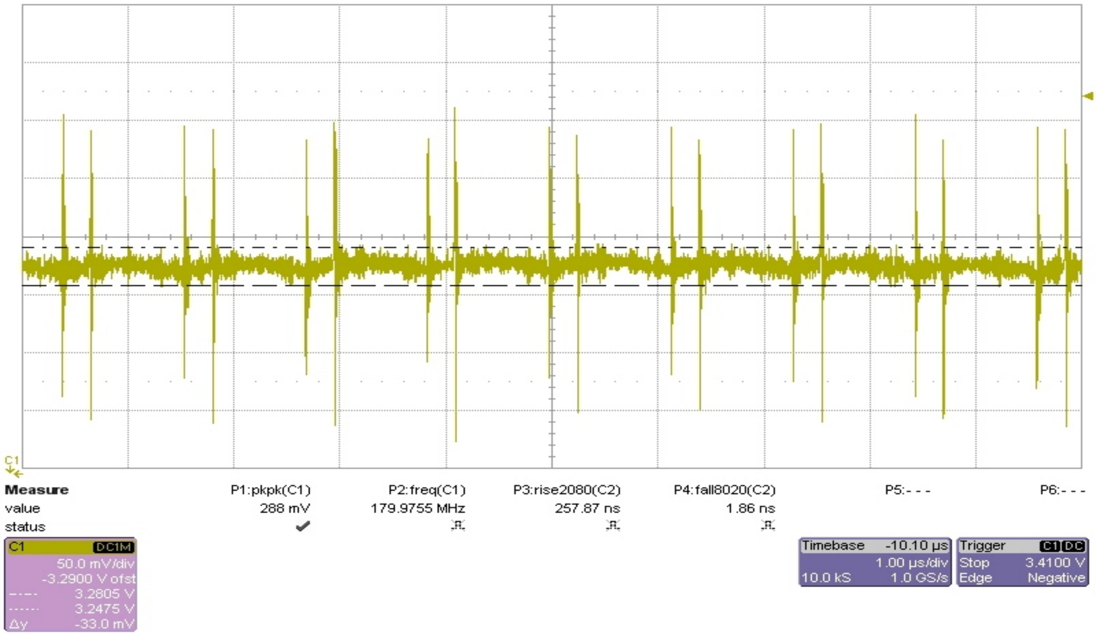
The input voltage over a range of 9 to 16V had little effect on the ST1S10 regulator, varying its output by only 1mV at each load tested (see Table 11). An increased current load had a more noticeable effect on the power supply's output than varying the input voltage. This result tops the load testing and input voltage testing of both the other tested power supplies.

I_out [A]	V_in [V]	V_out [V]
1.493	9.0	3.26
1.493	12.1	3.26
1.493	16.0	3.26
3.053	8.9	3.264
3.053	12.1	3.264
3.053	16.0	3.265

Table 11: Input voltage testing results for ST1S10.

3.3.4. Ripple Voltage

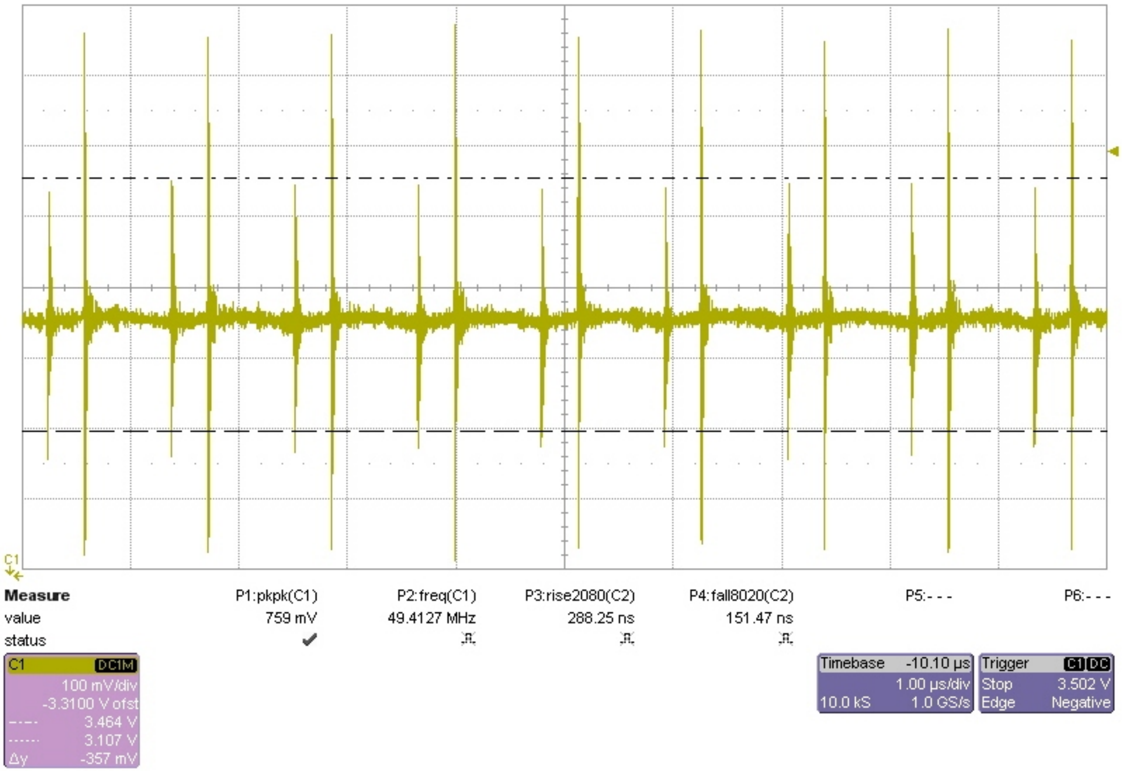
The ripple voltages of the ST1S10 switching power supply, recorded at 0.3, 1.5A and 3A loads, are shown below in Figure 12-Figure 14. The maximum voltage ripple, measured at a 3A load, was approximately 45mV. However, the disappointing artifact of the output waveform is the massive voltage spikes – almost 1.2V every cycle! Adding another 22µF capacitor in parallel at the output only reduced this phenomenon by approximately 20% - still the worst result observed in all the tested power supplies.



```
Measure     P1:pkpk(C1)   P2:freq(C1)    P3:rise2080(C2)   P4:fall8020(C2)   P5:- - -   P6:- - -
value       288 mV        179.9755 MHz   257.87 ns         1.86 ns
status      ✓

C1            DC1M           Timebase   -10.10 µs   Trigger   C1 DC
   50.0 mV/div                           1.00 µs/div  Stop     3.4100 V
  -3.2900 V ofst             10.0 kS      1.0 GS/s    Edge     Negative
-·-·-      3.2805 V
------     3.2475 V
Δy         -33.0 mV
```

Figure 12: ST1S10 ripple voltage with a 0.3A load.



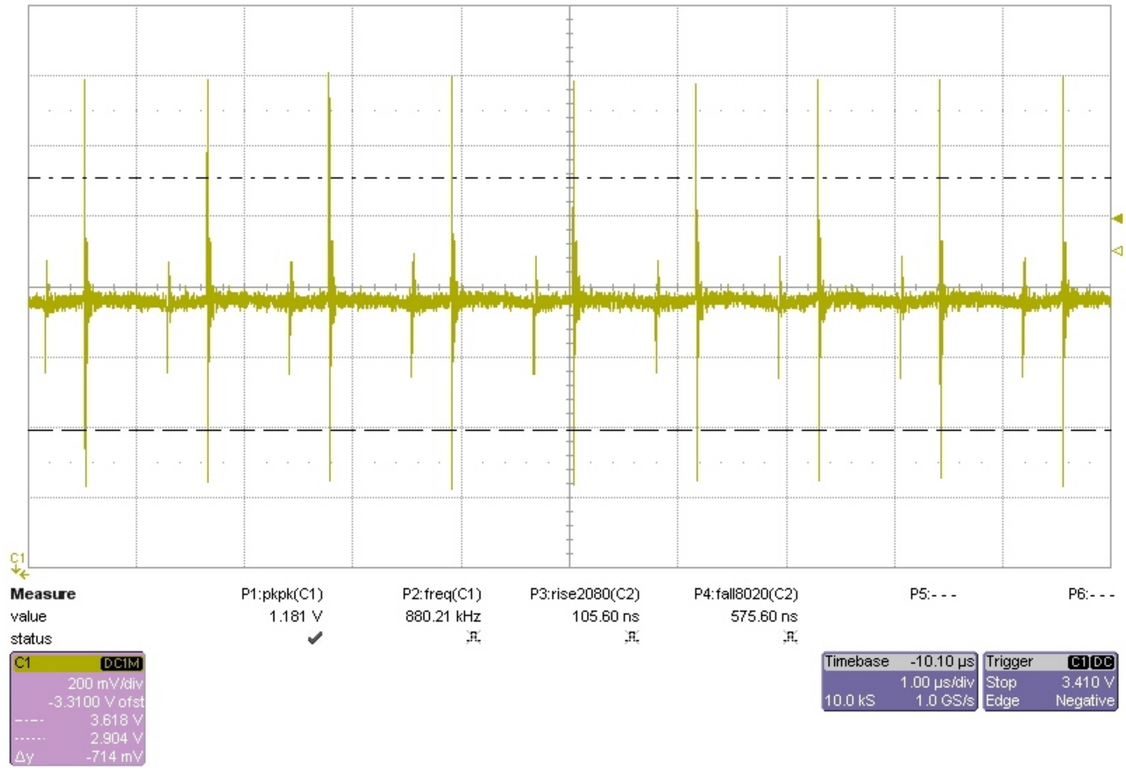
Measure	P1:pkpk(C1)	P2:freq(C1)	P3:rise2080(C2)	P4:fall8020(C2)	P5:- - -	P6:- - -
value	759 mV	49.4127 MHz	288.25 ns	151.47 ns		
status	✓	⎍	⎍	⎍		

C1 DC1M
100 mV/div
-3.3100 V ofst
3.464 V
3.107 V
Δy -357 mV

Timebase -10.10 µs
1.00 µs/div
10.0 kS 1.0 GS/s

Trigger C1 DC
Stop 3.502 V
Edge Negative

Figure 13: ST1S10 ripple voltage with a 1.5A load.



Measure	P1:pkpk(C1)	P2:freq(C1)	P3:rise2080(C2)	P4:fall8020(C2)	P5:- - -	P6:- - -
value	1.181 V	880.21 kHz	105.60 ns	575.60 ns		
status	✓	⎍	⎍	⎍		

C1 DC1M
200 mV/div
-3.3100 V ofst
3.618 V
2.904 V
Δy -714 mV

Timebase -10.10 µs
1.00 µs/div
10.0 kS 1.0 GS/s

Trigger C1 DC
Stop 3.410 V
Edge Negative

Figure 14: ST1S10 ripple voltage with a 3.0A load.

3.3.5. Transient Response

While already producing a current of 1.5A, an additional load of 1.4A was applied to the power supply. The output voltage drop – about 250mV, recovers with an estimated time constant τ ~ 25μs. The results are presented in Figure 15, and are compared to other switchers in Appendix B. The recovery time is similar to MAX15041, except that ST1S10 initially recovers quicker.

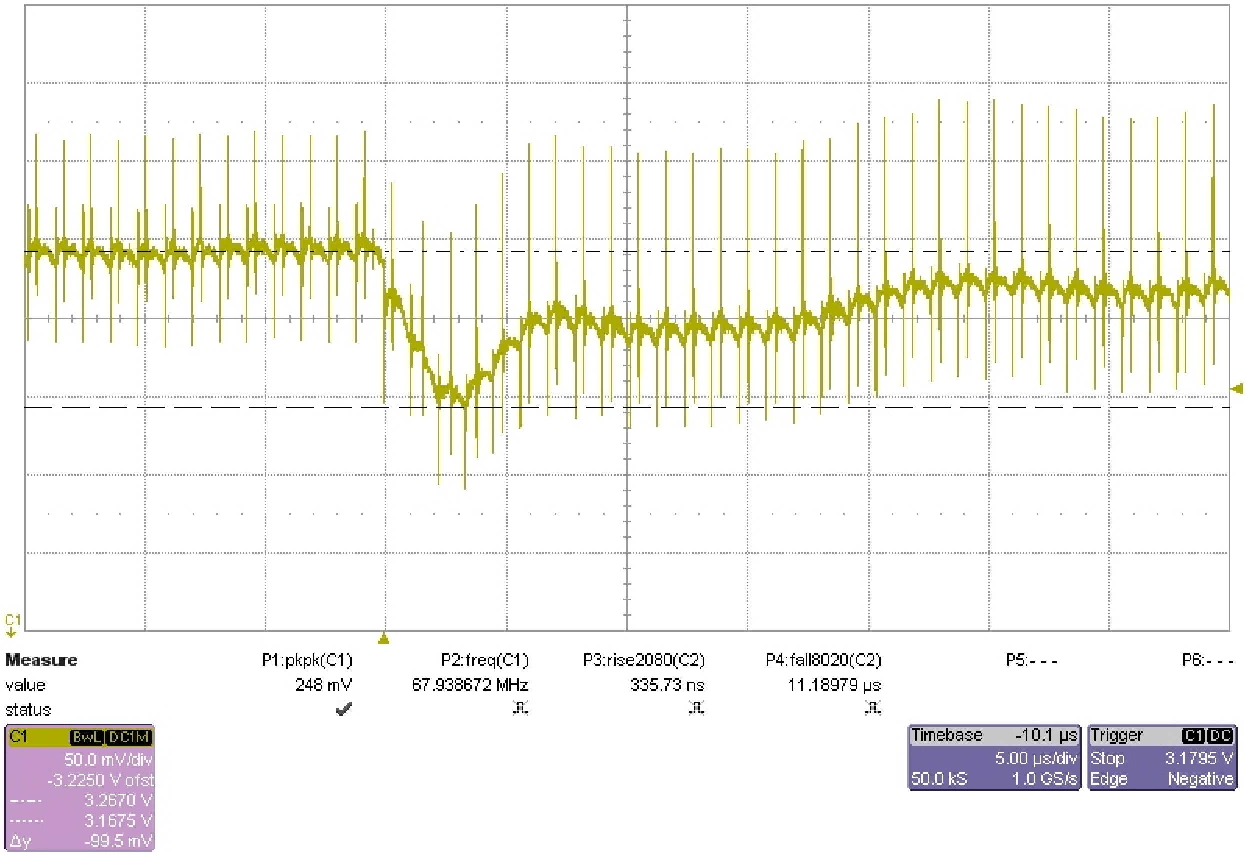


Figure 15: ST1S10 transient response, from 1.5A to a 2.9A load.

4. CONCLUSION

Using the given power requirements of Icron Technologies' PC-on-TV product (with the constraint of one power sequencing condition), a power architecture of step-down power supplies and linear regulators was developed for the PC board and TV board of the final product. The architecture calls for two switching power supplies capable of handling a 12V input and a 3A output to provide power at 3.3V and 5V. Following a rigorous financial assessment of each unit, Maxim's MAX15041, Monolithic Power Supply's MP2307 and ST Microelectronics' ST1S10 remained as viable contenders, and were evaluated for performance. Appendix B provides a summary of the notable features and capabilities of each of the three units.

Given that the primary criterion of assessment was the quality of the voltage output, MAX15041 was recommended for use in the product circuit board. Its ripple current, only 63mV peak-to-peak, was slightly inferior to that of ST1S10, but the voltage spikes on the output were by far the lowest. The spikes on ST1S10 had unacceptable levels greater than 1V. The load response and the transient response of the MAX15041 chip were again slightly poorer than that of ST1S10, but far superior to the MP2307. MAX15041 was the most expensive solution, costing $1.35 per voltage rail, while ST1S10 cost $1.21 and MP2307 - $1.27. However it was also the most efficient (see Appendices A and B), so it has the potential to save money by purchasing a smaller wall adaptor.

With the additional bonus of a power-good indicator, Maxim's power supply is a logical candidate for the developed architecture. It was implemented in the first revision of PC-on-TV product board schematic, and is expected to remain until production.

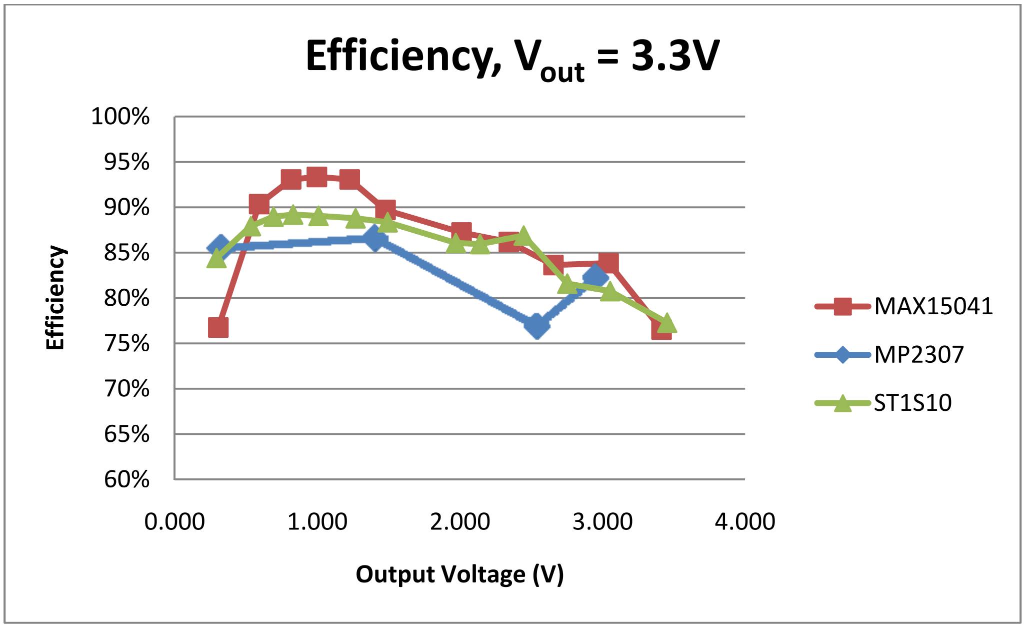
5. REFERENCES

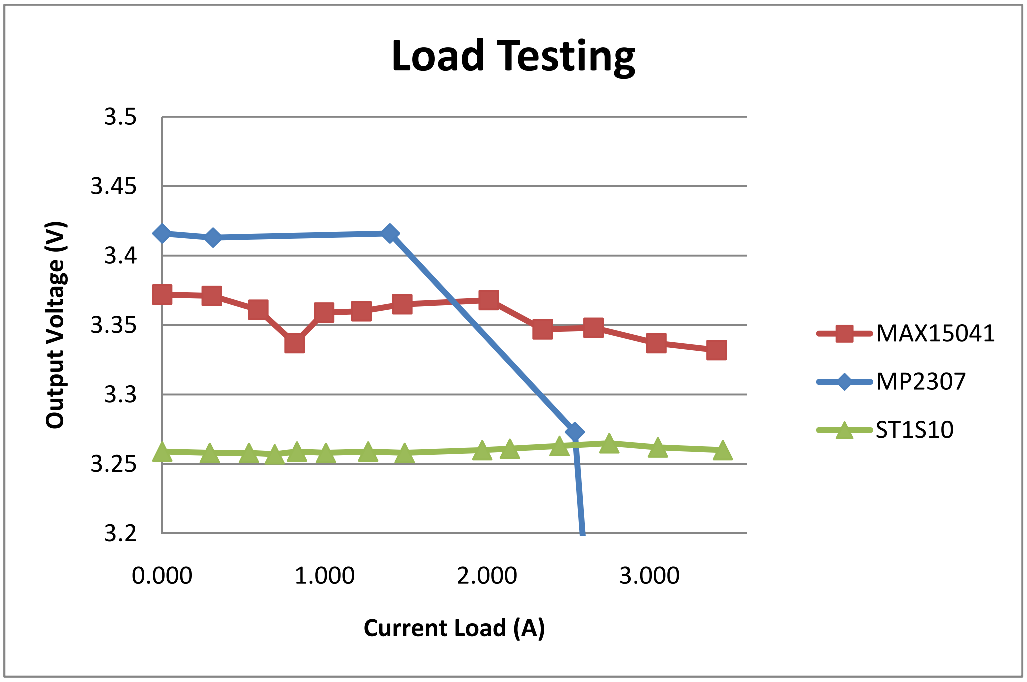
[1] MAX15041 datasheet. http://datasheets.maxim-ic.com/en/ds/MAX15041.pdf

[2] ST1S10 datasheet. http://www.st.com/stonline/books/pdf/docs/13844.pdf

APPENDICES

APPENDIX A: EFFICIENCY AND LOAD TESTING COMPARISON GRAPHS





APPENDIX B: 12V, 3A POWER SUPPLY TEST SUMMARY

	MAX15041		MP2307		ST1S10	
Price	$ 1.35		$ 1.27		$ 1.21	
V_{in}	4.5 ~ 28	V	4.7 ~ 23	V	2.5 ~ 18	V
V_{out}	0.6 ~ 24	V	0.9 ~ 20	V	0.8 ~ 18	V
Max Current	3	A	3	A	3	A
Switching Frequency	350	kHz	340	kHz	900	kHz
C_{in}	20	µF	20	µF	4.7	µF
C_{out}	10	µF	22	µF	22	µF
Inductor	6.8	µH	6.8	µH	3.3	µH
Power Good	Yes		No		No	
Enable	Yes		Yes		Yes	
Efficiency at 0.3A	77	%	86	%	84	%
Efficiency at 1.5A	90	%	87	%	89	%
Efficiency at 3.0A	84	%	81	%	81	%
Maximum Efficiency	93	%	87	%	89	%
Voltage Variation from Load	35	mV	786	mV	6	mV
Voltage Variation from V_in	9	mV	42	mV	1	mV
Maximum Ripple Voltage	63	mV	105	mV	45	mV
Maximum Voltage Spikes	160	mV	600	mV	1150	mV
1.5A Load Transient Response	270	mV	260	mV	250	mV
1.5A Transient Recovery Time	30	µs	50	µs	25	µs