ANLPS300: How to Power GSM/GPRS/EDGE/3G/HSPA M2M Modems

Optimized Power Scheme for High-Efficiency, Low Power Dissipation and Best RF Performances

Revision 1.0

General Description

Industrial applications for M2M data exchange are becoming increasingly common; a fact supported by the wide availability of easy-to-use cellular modem modules. Depending upon the application, modem use, and cellular network density, the power consumed by the modem itself can vary greatly. Modem modules from suppliers such as Sierra Wireless, Cinterion, Telit, Gemalto, Sierra Wireless, and others handle all the RF and protocol functions required for an embedded device to operate on a 2G, 3G, or 4G cellular telephone network. This still leaves the system designer to implement a power circuit that ensures the modem operates in accordance with its specifications across the entire operating temperature range and under any network conditions. Moreover, most M2M module datasheets do not give in-depth technical information necessary to correctly design the power rail and frequently provide numbers in perfect antenna conditions. This application note describes the challenges facing the power circuit designer and describes how to find the right balance necessary to power such modems with respect to:

- Cost
- Size
- Power efficiency
- Power consumption
- EMI
- Risk (certification)

Datasheets and support documentation for all the devices mentioned in this application note are available on Micrel's web site at: www.micrel.com.

Glossary

- COT – Constant on-time
- M2M – Machine to machine
- EMI – Electro-magnetic interference
- ESR – Equivalent series resistance
- PCB – Printed circuit board
- PA – Power amplifier
- PAPR – Peak-to-average power ratio
- POL – Point of load
- TDD – Time division duplex
- FDD – Frequency division duplex
- TS – Time slot
- VSWR – Voltage standing wave ratio

Modem Transmit Power

Depending on the modulation used by the module and its power class, cellular modems require large variations in transmit power. Spread spectrum techniques used in 3G (WCDMA, HSDPA, HSUPA) provide ways to improve data rates with lower peak power and sometimes lower average transmit power. Two major parameters have to be taken into account to accurately determine the power supply of a cellular modem:

- Peak transmit power that will determine power supply peak current.
- Average transmit power that will determine power dissipation.

Peak Transmit Power

Backward compatibility is always required with GSM in order to ensure the best network coverage. GSM/GPRS needs to be taken into account in any cellular application. As shown in Figure 1, GSM/GPRS is typically the most important parameter used to determine the peak current that a power supply has to sustain. PAPR stands for peak-to-average power ratio. This ratio is average power required vs. peak power required in a given mode. GSM typically requires high peak power while average power remains low. The 33dBm required, seen in Equation 1, means that output power is close to 2W at the antenna.

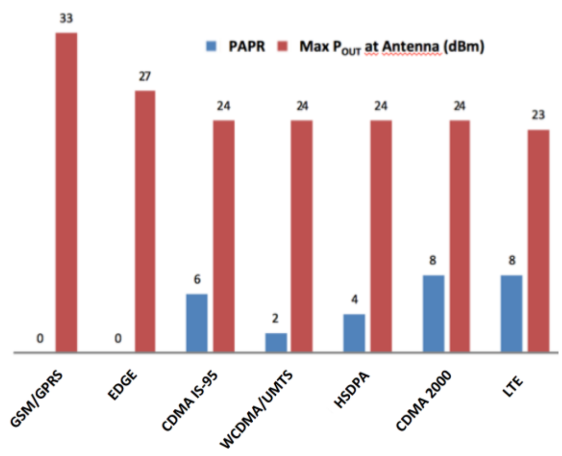


Figure 1. Peak Antenna Power vs. Access Mode

$$10\text{Log}\left(\frac{P_{OUTMAX}}{1\text{mW}}\right) = 33\text{dBm}$$

$$P_{OUTMAX} = \left(10.\frac{33\text{dBm}}{10}\right) \div 1000 \approx 2\text{W} \qquad \textbf{Eq. 1}$$

Figure 1 shows transmit power at the antenna. This is the equivalent of the effective power as seen by the network. Figure 2 shows the typical implementation of the modem using a M2M module.

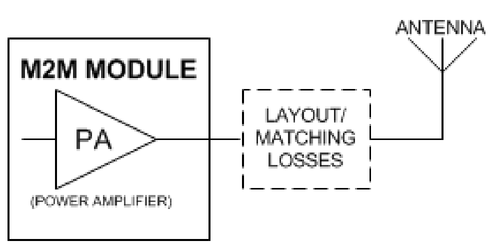


Figure 2. M2M Module

M2M modules always integrate the PA. However, it does not usually integrate the antenna nor the antenna connector. Usually, the module provides standard pins that need to be laid out to the antenna or to the antenna connector. Depending upon the antenna chosen and type of connection, the power efficiency can vary significantly. Moreover, the antenna/module connection needs to be matched in impedance at the working frequency. A matching network is never perfect and induces some power losses. The VSWR parameter allows the user to measure antenna and matching network losses to show a system efficiency value for the power seen at the antenna. A reference table of power transmission losses vs. VSWR is provided on the Skyworks website:

http://www.skyworksinc.com/uploads/documents/vswrreturn.pdf

Ideal VSWR for antennas is in the range of 1.5; mid-range is usually between 2.0 and 2.5, while bad antennas are 3.5 or above. Typically, 3.5 VSWR means losses of -1.6dB.

The PA output usually exhibits some power headroom to ensure +33dBm power at the antenna. Taking into account the guard band of -1.5dB in losses (antenna efficiency/loss + PCB/matching losses) raises PA output power to +34.5dBm. In this case, as per Equation 1, $P_{OUT(MAX)} \approx 2.8W$. The +1.5dBm margin drives power on the PA to be raised by 40%.

PAs are generally rated between 45% and 60% efficiency. The PA efficiency is given by the ratio between power provided to the load (antenna and matching network) and the power consumed on its main power rail (Vcc). Depending on the M2M module's Vcc range (usually 3.2V up to 4.2V to support Li-Ion batteries), the input current can vary greatly. Figure 3 shows peak current depending upon VCC voltage and on PA efficiency. Please note that Figure 3 assumes that matching network to the antenna, and the antenna itself are very good (meaning low losses or ideal antenna and PCB conditions. These are often numbers that are given in the module's datasheet.).

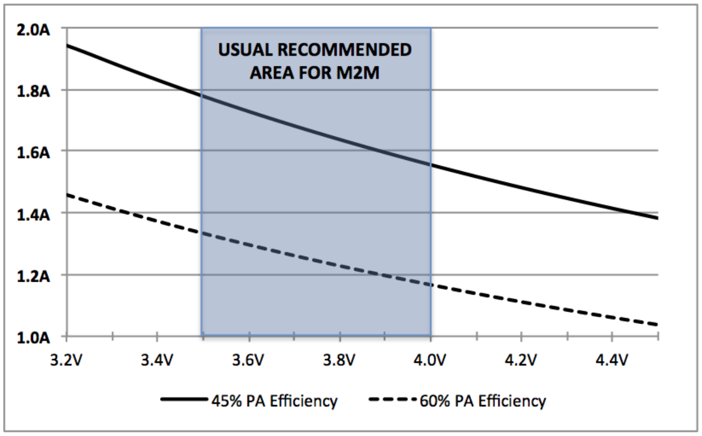


Figure 3. PA Peak Current vs. VCC and PA Efficiency with Ideal Matching and Antenna

Under certain conditions, the antenna can be very poor. Most M2M applications use a single antenna design while the modem operates over multiple bands. This means most applications use a large bandwidth antenna that has lower efficiency than a narrow band antenna. This becomes even more the case for PCB antennas. Constraints in this application prevent good antenna efficiency. Usually, M2M modem manufacturers specify peak current at 33dBm (or 34.5dBm) transmit power, but manufacturers usually assume their antennas operate in an optimal range. That is why, in most of the specifications, manufacturers define modem peak current at 2A or below. This number has to be taken with caution. A safer design would be to use 2.5A as the right value to measure the power rail. Doing so helps to compensate power losses due to the PCB, matching, and antenna. In such cases, peak current can reach up to 2.5A, as shown in Figure 4 and Figure 5.

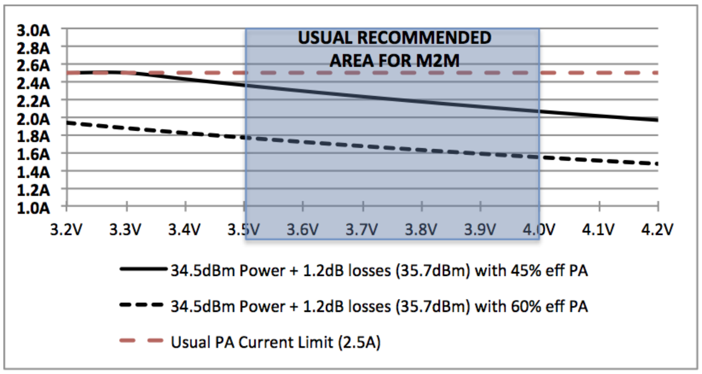


Figure 4. Real PA Peak Current vs. VCC

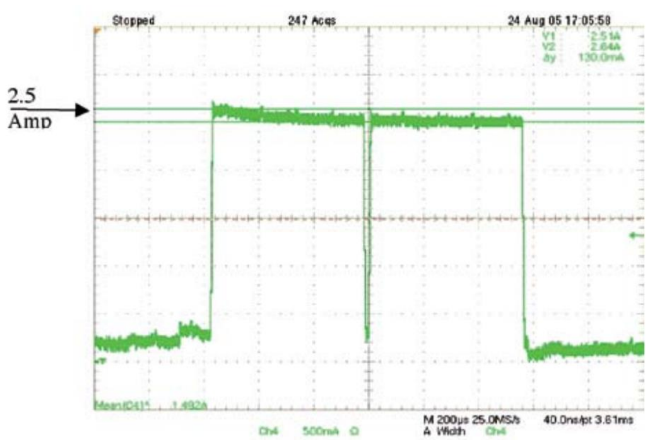


Figure 5. PA Peak Current in GPRS Class 10 (2xTX time slots) in bad antenna conditions

Usually, the PA does feature internal current limitation to avoid any damage and to ensure transmit power will not exceed regulation limits. As a result, in most power amplifiers, the peak current consumption limit is set to 2.5A.

Moreover, circuits other than the PA are powered by module's main power input (VCC), such as the RF transceiver, baseband CPUs, and more. This could add an overhead of 500mA peak current.

As a general rule, 2G (GSM/GPRS) is the worst case condition for peak current and 3A peak current is the appropriate boundary at which to size the power rail.

Average Transmit Power

In 2G mode (GSM/GPRS/EDGE), the transmission is not continuous but multiplexed in time domain; this is also called time division duplex (TDD). Using TDD means that at a given frequency, the cellular modem is using a given number of timeslots depending on network capabilities and the type of connection. This also depends on capabilities of the modem.

Figure 6 shows how a 2G frame is organized (time multiplexing). A time slot can be a transmit slot or receive slot. This depends on network allocations and that also depends on type of connection used.

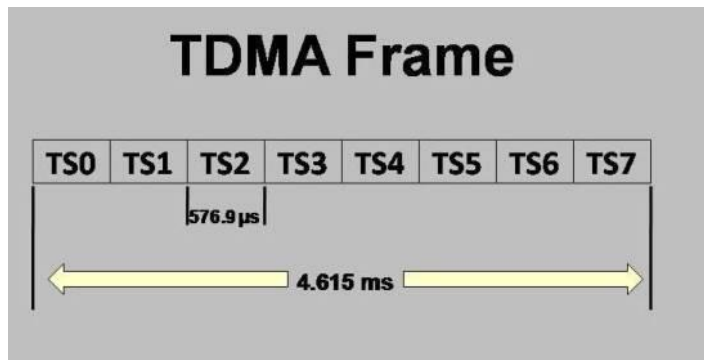


Figure 6. TDMA Frame Time Slots

Once a frame has been processed, a new one occurs. Figure 7 shows how frames are managed over time.

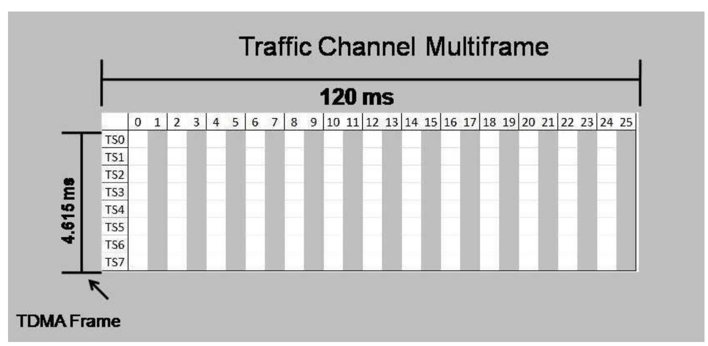


Figure 7. Multiframe Time Multiplexing

One key parameter is to determine the highest Multislot Class that an application can use. This will mainly depend on the modem's capability. Figure 8 shows the time slot allocations depending on the Multislot Class used. For instance, a GPRS Class 10 capable modem can use up to two uplink time slots while an EDGE Class 12 capable modem can use up to four uplink time slots.

Multislot Class	Downlink TS	Uplink TS	Active TS
1	1	1	2
2	2	1	3
3	2	2	3
4	3	1	4
5	2	2	4
6	3	2	4
7	3	3	4
8	4	1	5
9	3	2	5
10	4	2	5
11	4	3	5
12	4	4	5
30	5	1	6
31	5	2	6
32	5	3	6
33	5	4	6
34	5	5	6

Figure 8. Multislot Uplink Time Slots Allocations

Depending upon the modem used and its capabilities, the data transmission can use 1, 2, 3, or 4 time slots among the 8 available within a given frame. Regular capabilities seen in the market are usually GPRS Class 10 (2 Uplink TS), EDGE Class 12 (4 Uplink TS).

This being said, 3G networks also significantly impact average current consumption due to the fact that those are not multiplexed in the time domain. Transmission and reception are continuous once a connection becomes active. Table 1 shows the average current consumption depending on mode in use.

Table 1. Typical Average Current Consumptions vs. Mode

Mode	Max. Average Current	Conditions
GSM	<550mA	1 uplink TS @ 33dBm
GPRS Class 10	<700mA	2 uplink TS @ 26dBm
EDGE Class 12	<600mA	4 uplink TS @ 28dBm
3G + HSDPA	<800mA	64kbps UL @ 22dBM/3.6Mbps DL
3G + HSUPA	<800mA	3.6Mbps UL @ 23dBm/64kbps DL

Note:

Data from USB dongle with a bad antenna or PCIe module at 3.3V. This reflects full modem consumption, not only the PA. Data above includes 20% margin vs. measurements.

Table 1 demonstrates that, from the point of view of average current, there is no significant difference between 2G (GSM/GPRS/EDGE) and 3G. A safe design rule is to take into account 1A average current in the least optimal conditions.

Transmit Power Timings

As 2G modes (GSM, GPRS, EDGE) are time-slotted, it is required to comply with ramp-up/ramp-down power time masks. Figure 9 and Figure 10 show the power ramp-up/ramp-down time masks in single slot transmit mode and in multislot transmit mode. Assuming peak power is +33dBm at the antenna, then we can correlate this transmit power with a peak current consumption of 2.5A as explained in the Peak Transmit Power section. It is necessary that the power rail be fast enough to not degrade this response time. Figure 9 shows that ramp-up/ramp-down must be contained in 28µs maximum. Figure 10 adds another dimension in multislot considerations where the adjacent ramp-down and ramp-up must be contained in 36.9µs maximum. As a consequence, the least optimal scenario features a power step every 17 to 18µs.

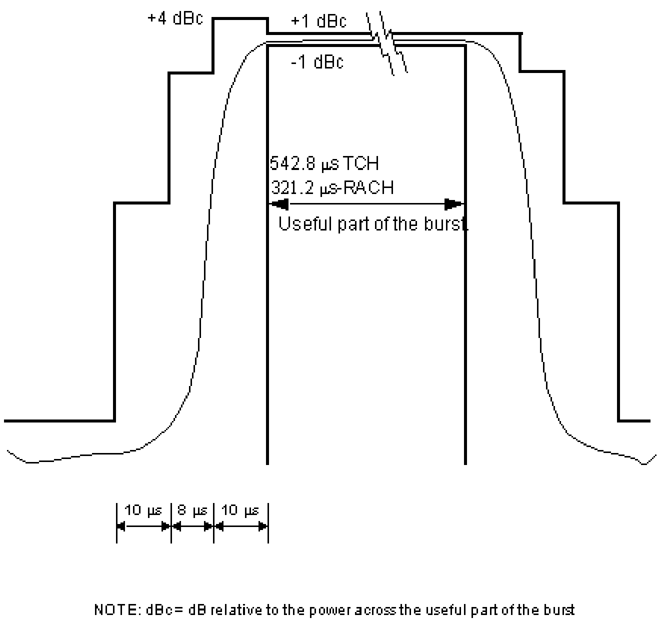


Figure 9. Single Slot Time Mask

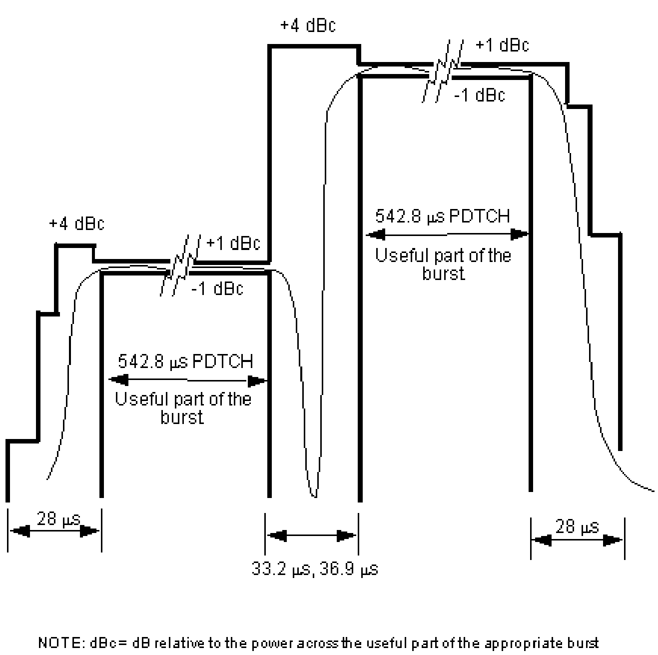


Figure 10. Multislot Time Mask

In order to ensure power supply transient response does not degrade the modem's performance, output voltage transient response must be very fast and as stable as possible. If the power supply is too slow, the output voltage might drop too much and result in a time mask violation. This would cause the modem to behave poorly or have issues in high-power conditions, such as affecting network cell range limit.

A common way of fixing this is to use large output capacitors to provide enough energy to the modem during high load transients. However, drawbacks to this solution include the fact that:

- Large capacitors are expensive and consume lots of board space.
- Large capacitors will not be able to react fast enough in high frequency situations.
- Large capacitors usually feature high ESR that adds a low frequency pole-to-open-loop response. The consequence is that the system reacts slow to load transients because the open loop gain margin is impacted by this additional pole.

The safe design rule is to select a fast power supply that does not need very big output capacitance. Fast load regulation can be achieved by using:

- A high-speed LDO with good phase margin. Better stability provides for fewer over/undershoots.
- A DC-to-DC step-down converter with high switching frequency to address fast load transients.

Spectrum/RF Dependencies

The 2G mode uses narrow-band frequency channels that are spaced every 200kHz (400kHz bandwidth). 3G (UMTS, HSPA) mode uses a wide-band spread-spectrum (5MHz). LTE is an OFDM scheme with multiple carriers spread over a bandwidth of 1.2MHz up to 20MHz. This can also be assimilated as a wide-band system.

In wireless applications, it is important that EMI/spur sources on the design do not significantly disturb the RF signal. This strongly impacts the sensitivity of the modem which could cause the device to have poor range, coverage, degraded data rates, and increased error rate.

With this in mind, it is better to optimize the M2M module power supply so it does not generate emissions/spurs that can be mixed with high RF frequencies. However, this does not mean that using a DC-to-DC converter is prohibited. It does suggest special care has to be taken.

- Use a high switching frequency DC-to-DC converter to space spurs in order to avoid too many in-band blockers. 100kHz DC-to-DC converters will generate spurs every odd multiples of 100kHz (100kHz, 300kHz, 500kHz, etc.) while a 1MHz DC-to-DC converter will generate spurs at odd multiples of 1MHz (1Mhz, 3MHz, 5MHz, etc.) We can see here that spurs are more spread and less present in the band used.
- Use shielded inductors.
- In layout, take care to limit the length of traces with high energy (high dV/dt or di/dt), like switching nodes.
- Avoid traces under inductor and split grounds.
- Use a high inductance value to limit inductor ripple and peak current. It is a common mistake to decrease the inductance value when increasing the switching frequency. Keeping the same inductance value reduces ripple current and the saturation rating of the inductor. It also generates fewer energy spurs (lower di/dt). On the other hand, increasing inductor value does make DC-to-DC reacting slower, which impacts load regulation and creates potential time mask violations.

Figure 11 and Figure 12 show typical good and bad RF spectrums for a GSM channel. Many reasons can cause the out-band spurs shown in the failed spectrum, but power rail design is one of the biggest contributors. These factors that contribute to bad RF spectrums often mean that device cannot pass the certification.

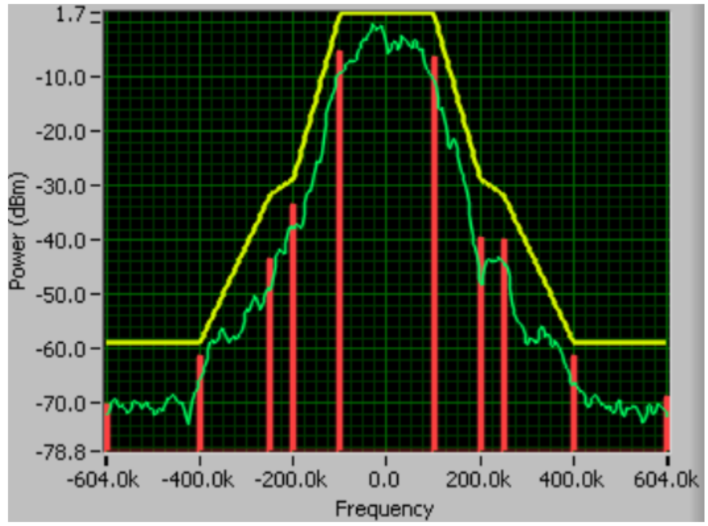


Figure 11. GSM Spectrum (Passed)

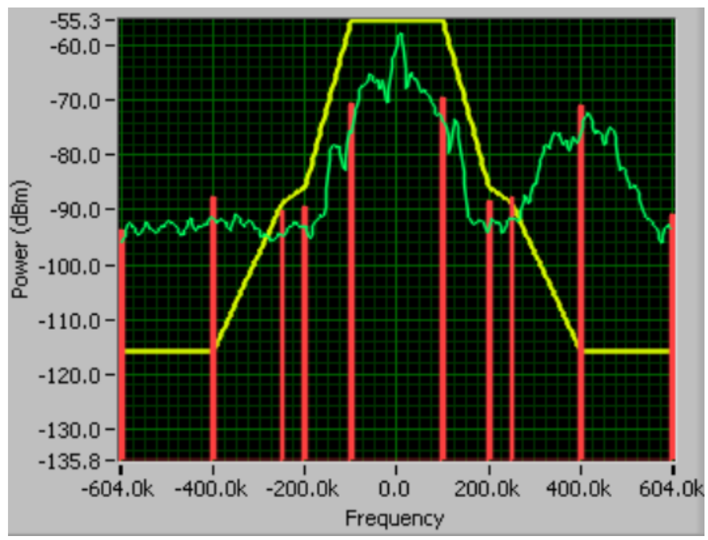


Figure 12. GSM Spectrum (Failed)

Power Solutions

Solutions Overview

Designing the power supply for cellular modems can differ significantly depending on application constraints such as cost, size, efficiency, and power dissipation.

When starting a design, it is important to understand any tradeoffs that are needed. It is impossible to optimize the design in one area without impacting others. Figure 13 depicts the advantages and disadvantages of each solution.

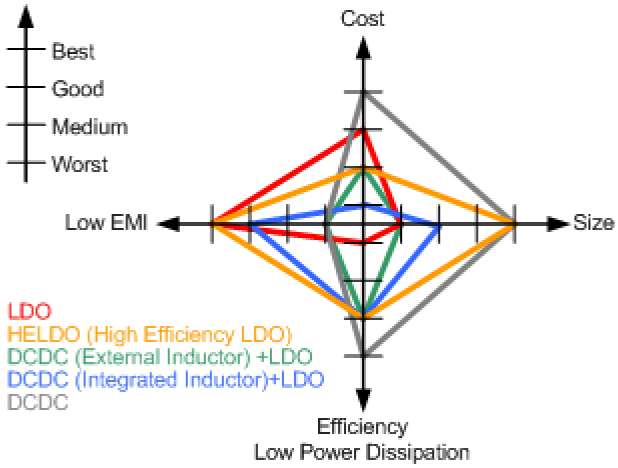


Figure 13. Solutions Overview

The most straightforward solution is to use an LDO, but there are drawbacks that might cause designers to think otherwise in M2M module applications.

- Modem power supply must be fast and provide very good load and line regulation in order to maintain modem performance. Thus, the design needs a high performance LDO. A high current LDO at 2A or higher usually requires a large package in order to sustain high power dissipation in most applications. This large package, combined with high performance, means a higher cost device. For this reason, the LDO is not always the most cost-optimized solution.
- Poor efficiency of an LDO drives power dissipation, board heat, and high power consumption. Consequently, these designs require a large PCB heatsink. This consumes valuable board space and sets limits for space constrained applications.

In reality, the most cost-optimized solution is to use a DC-to-DC step-down converter. However, this solution also creates some drawbacks.

- The voltage rail that is provided to the modem directly powers the PA. This means the voltage rail is very sensitive to large ripple. The rail could significantly impact modem performance in terms of sensitivity (range) and EMI.
- A DC-to-DC step-down converter, in fixed frequency architecture, features bad load regulation. If a load transient (transmit slot) occurs in the middle of a switching cycle, the voltage will undershoot until the DC-to-DC converter recovers the output voltage over the next few cycles. This impacts the power ramp-up/ramp-down time mask. Using COT architecture helps for faster reaction as well as increased switching frequency. However, this generates moving frequency spurs that require special care in PCB layout and component choice. If fixed frequency PWM is used, then it must feature large loop bandwidth for faster load regulation without showing instabilities like oscillations or significant overshoots/ undershoots.
- From an efficiency standpoint, a DC-to-DC step-down converter offers the best performance, but they require special care in PCB layout design and in inductor/capacitor selection. Although lowering switching frequency helps improve efficiency, it also increases in-band spurs/noise and degrades load regulation. In order to minimize issues, at least 1.7MHz switching frequency is recommended.

Size is key in space-constrained applications. According to what has already been presented, an LDO is clearly not best size option for such high output current. A DC-to-DC step-down converter is shown as the best alternative, but also demonstrates sub-optimal performance in terms of EMI and RF.

As a result, two solutions clearly show the best balance:

1. The HELDO™ (High Efficiency LDO), which provides the lowest EMI and best RF performance with good balance in size, cost, and efficiency. It is the most balanced solution without clear weaknesses. It is the best solution for short time-to-market and low risk.
2. The DC-to-DC converter, which provides the best cost, size, and efficiency solution with an EMI/M2M RF performance penalty. The design requires special care and most likely some tuning during the testing phase that might drive new PCB revisions and deeper validations.

Optimized Solutions for >5V Input Voltage

Depending upon the application, the main input voltage can be high (12V, 24V, 48V, 60V, 80V, etc.). The first step is to design a power supply that builds a 3.6V to 3.8V rail that directly powers the M2M module. In that case, using a DC-to-DC converter is mandatory because of power dissipation. The issue with such a design is that the higher the voltage drop between input and output, the lower the switching frequency of a DC-to-DC converter becomes. The main reason for this is to limit switching losses that can greatly impact efficiency. Moving to a lower switching frequency also drives higher peak current in the inductor. As a result, the inductor saturation current rating must be high, which increases the overall size of the device. Moving to a bigger inductor in terms of power and size avoids the capability of also using high switching frequency. The bigger the inductor, the weaker it is in higher frequencies. One other side effect of moving to a low switching frequency is slow load regulation. Issues regarding M2M module time mask may also occur.

Therefore, for high input voltage applications, a two-stage regulation is mandatory (see Figure 14).

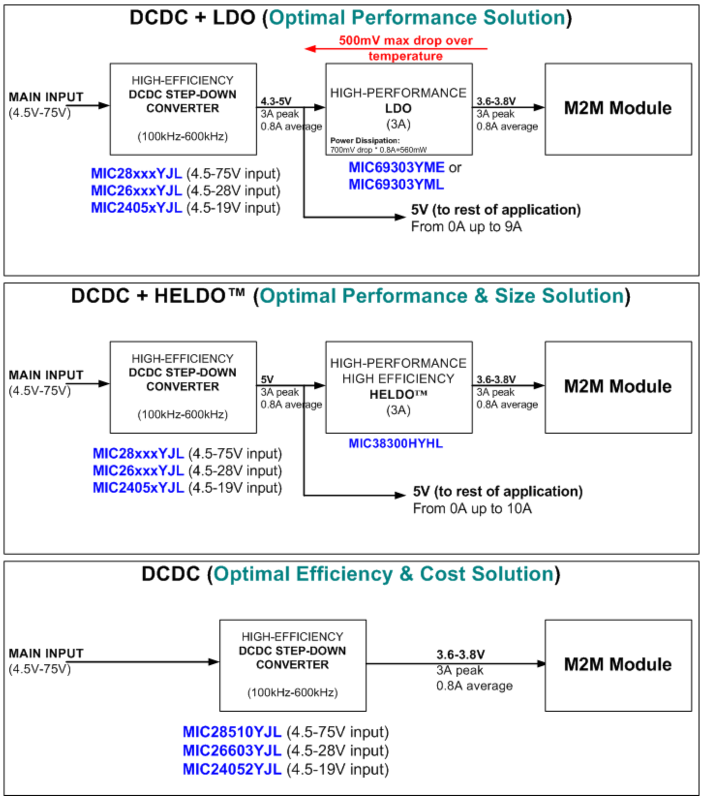


Figure 14. High-Input Voltage Solutions

Figure 14 depicts three solutions, the first two being the recommended ones. Those recommended solutions are based on a first stage that features a DC-to-DC step-down converter that generates a rail at 5V. This rail powers the rest of the application and feeds a high-speed/low-ripple second stage that handles M2M module power. This second stage can be one of two options:

1. A high-speed LDO that must sustain 3A peak current and must be capable of dissipating 1W at maximum ambient temperature (MIC69303YML). An LDO is still a valid solution for applications that are not space-constrained, that do not need high efficiency, and that use low input voltage (≤5V).
2. A HELDO™ (High Efficiency LDO, MIC38300HYHL) that provides the same performance as a high-speed LDO, but with improved efficiency. This solution actually embeds a DC-to-DC converter that integrates the inductor. This integrated DC-to-DC converter internally feeds an ultra-fast/low-noise LDO. As a result and from a system perspective, it looks like an LDO, but with enhanced efficiency. The HELDO solution provides a low-EMI solution that decreases power dissipation.

This is important to optimize efficiency, cost, and size. Therefore, Micrel recommends using the SuperSwitcherII™ family as a first conversion stage (see Figure 14). This provides a way of having a scalable and flexible design with a good balance in terms of cost and integration. All devices are in a 5mm × 6mm MLF® package and integrate synchronous MOSFETs. The whole family is based on Hyper Speed Control™, which uses Micrel's distinct architecture for downsized input and output capacitors compared to regular architectures. High voltage capacitors on input impact much in terms of cost and size. The main reason is to filter out input current ripple that could lead to excessive output noise and load regulation issues. With Hyper Speed Control™ architecture, this effect is suppressed by a system that anticipates such variations. In other words, input capacitance can be significantly lowered without impacting output voltage ripple and load regulation. This family has been designed for such high voltage drop applications.

Within the family, there are two types of devices:

1. Hyper Speed Control-only devices.
   a. MIC28510 for 4.5V to 75V input voltage range and up to 4A output current.
   b. MIC26601/MIC26901/MIC261201 for 4.5V to 28V input voltage range with 6A, 9A, and 12A output current respectively.
   c. MIC24051/MIC24053/MIC24055 for 4.5V to 19V input voltage range with up to 6A, 9A, and 12A output current respectively.
2. Hyper Speed Control and HyperLight Load® that offers the same advantage as the Hyper Speed Control-only devices, but with high-efficiency at light loads. This is critical for battery-powered applications that need to minimize power consumption when the M2M modem is in standby mode (no data transfer, but camped on the network). These devices include:
   a. MIC26603/MIC26903/MIC261203 for 4.5V to 28V input voltage range with up to 6A, 9A, and 12A output current respectively.
   b. MIC24052/MIC24054/MIC24056 for 4.5V to 19V input voltage range with up to 6A, 9A, and 12A output current respectively.

Optimized Solutions for ≤5V Input Voltage

When the main input voltage is 5V or below, like for applications using AC/DC 5V power supply or USB power input, the best solution highly depends on constraints as shown in Figure 13. Those constraints are mainly driven by size and cost. The smallest size will need the most integrated solution, with highest efficiency possible so as to avoid power dissipation issues. In the same way, EMI must be as low as possible to avoid adding shielding or filtering. Figure 15 shows the solutions that include:

- A DC-to-DC converter that optimizes cost, size, and power dissipation while having to accept the degraded EMI/high ripple performance that induces degraded RF performances (smaller range/coverage, lower data rate), more complex PCB, more PCB re-spin risk, more design tuning and test (certification risk). The device proposed is the MIC2207YML high efficiency, high switching frequency DC-to-DC converter.
- A HELDO device that optimizes size and performance with good efficiency, excellent load regulation, low ripple, excellent EMI performance, and best integration. This solution also provides faster time-to-market development as it minimizes design risks.
- An LDO that optimizes cost and EMI while accepting a large overall design size (PCB heatsink) and higher power dissipation (MIC69303YML).

Figure 15 summarizes the three solutions and part numbers proposed for the 5V main input applications.

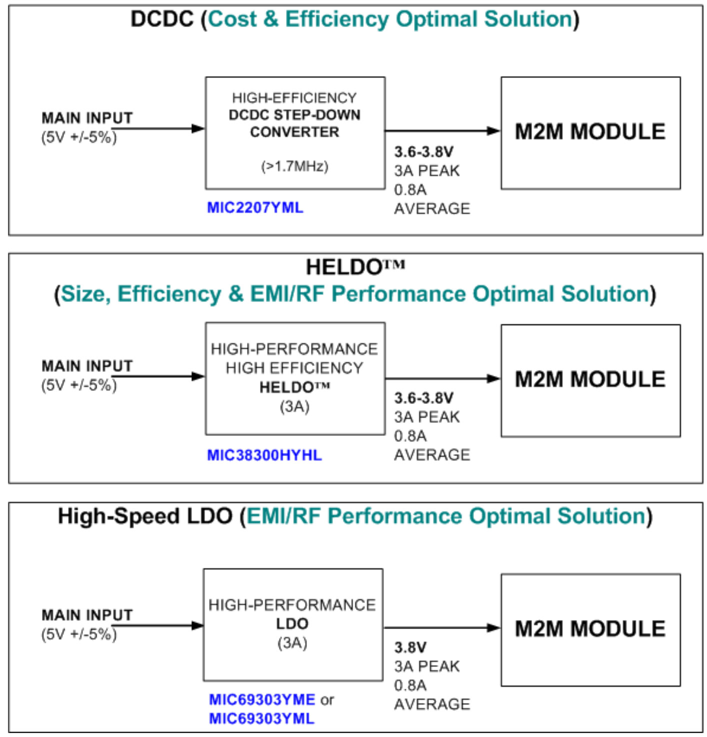


Figure 15. 5V Input Resources

Design Inputs and Resources

This section aims to provide a brief overview of devices and resources available to help designers.

As seen in Figure 14, for recommended solutions, high input voltage applications (higher than 5V nominal) first require a regulation stage that provides a main 5V rail to the rest of the application, including the M2M module. Having this optimized first stage allows designers to use small, low-cost POL regulators. Low voltage drop provides a way of using high switching frequency devices that lead to very small, low-cost inductors and capacitors. Moreover, this improves performances in load/line regulation performances.

In Figure 15, 5V input applications are based on the same HELDO device (MIC38300HYHL) for the best balanced and lowest risk solution. For applications that are heavily constrained by cost, MIC2207YML provides an efficient solution with small size. Keep in mind this solution might need further design tuning due to DC-to-DC parasitic effects such as output ripple and switching parasitics.

Device Resources

For all the devices listed in this section, please visit www.micrel.com for more details (datasheets, evaluation boards, design kits, and additional collateral).

MIC26601YJL/MIC26901YJL/MIC261201YJL/ MIC24051YJL/MIC24053YJL/MIC24055YJL

MIC26601YJL operates within the 7V to 28V input voltage range. This device provides up to 6A output maximum. In M2M applications, the modem is the only powered device. Therefore devices with current higher than 3A peak provide some headroom to power the rest of the application. MIC26901YJL (9A maximum) and MIC261201YJL (12A maximum) provide pin-to-pin compatible solutions for higher current applications. For smaller input ranges of 4.5V minimum up to 19V maximum, MIC24051 (6A maximum), MIC24053 (9A maximum), and MIC24055 (12A maximum) offer pin-to-pin compatibility with the MIC26x01 series. An important parameter in these designs is to evaluate the power dissipation required at maximum ambient temperature. Efficiency greatly depends on input voltage range. As shown in Figure 16, the 5V output efficiency is around 94% at a 12V input and 92% at a 24V input. Those measurements are given for a temperature of 25°C. Unfortunately, with MOSFET temperatures rising, MOSFET RDSon significantly increases and induces a degraded efficiency. This generally results in around a 5% loss in efficiency while running at higher temperatures.

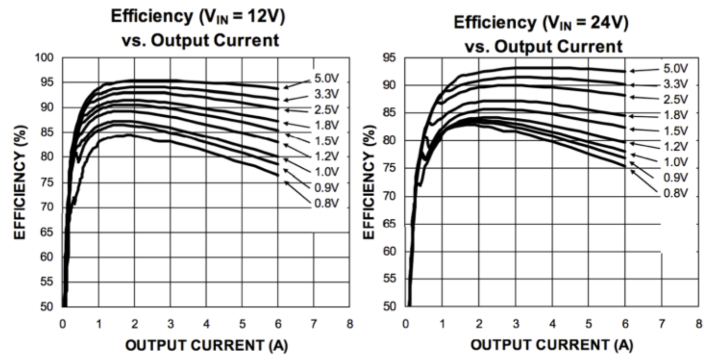


Figure 16. MIC26601YJL Efficiency vs. Output Current

For example, a 24V main input will give an average efficiency at around 87% at high temperature. The output power is given by:

$P_{OUT} = V_{OUT} \times I_{OUT}$

Power to be dissipated is then:

$P_{DISS} = P_{OUT} \times (1\text{-}87\%)$

Now, assuming that dissipated power is given by:

$P_{DISS} = (T_{JMAX} - T_{AMAX}) \div R_{TH}$

The maximum output current is:

$I_{OUTMAX} = (T_{JMAX} - T_{AMAX}) \div (R_{TH} \times V_{OUT} \times 87\%)$ for 24V input

$I_{OUTMAX} = (T_{JMAX} - T_{AMAX}) \div (R_{TH} \times V_{OUT} \times 90\%)$ for 12V input

with:

- Θ_{JA} is the package thermal resistance (28°C/W).
- TJ_{MAX} is the maximum junction temperature (+125°C).
- T_{AMAX} is the maximum ambient temperature.
- V_{OUT} is the 5V output voltage.

Even if the MIC26601YJL can sustain 6A output peak current, the average output current is determined by the application maximum ambient temperature. Figure 17 shows what maximum average output current can be achieved with the MIC26601YJL depending upon the ambient temperature and input voltage.

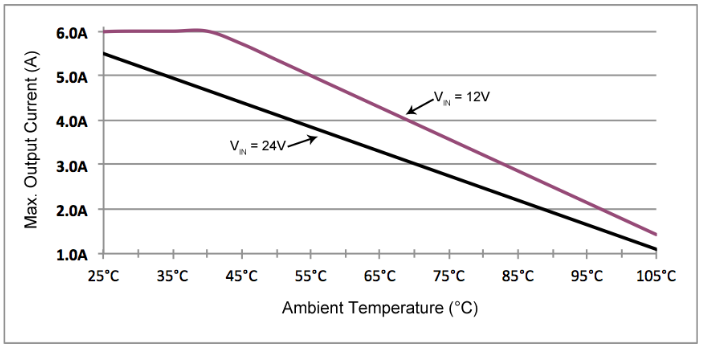


Figure 17. MIC26601YJL and MIC26603YJL Maximum Average Output Current vs. Ambient Temperature

In the least optimal scenario, the M2M module can require up to 800mA average current. This leaves 1.4A (24V input) and 2.1A (12V input) for the rest of the application at +85°C. At +55°C ambient temperature around the device, extra current for the application is 3A at 24V input and 4.2A at 12V input.

MIC26603YJL/MIC26903YJL/MIC261203YJL/ MIC24052YJL/MIC24054YJL/MIC24056YJL

MIC26603YJL is similar to MIC26601YJL for high loads (≥1A). The main difference is related to light load mode. Many M2M applications only enable the M2M module when a connection is required to send and receive data. This means that the 5V rail is only sometimes loaded with the M2M module. Applications generally use processors or devices that exhibit wide load variations depending upon system activity. Consequentially, the 5V load can vary widely from very light current up to very high currents. For some applications, it is important to keep system current consumption as low as possible, which means running at the highest efficiency in all system states. This is particularly true for systems that take their main power from a limited energy source, like a battery or a solar panel. MIC26x03YJL devices feature HyperLight Load, Micrel's architecture that drives the DC-to-DC converter into a low power mode automatically when load is low. This ensures optimized efficiency even when the system is in standby mode (80% at 10mA load). The maximum output current available depending on ambient temperature is the same for MIC26601YJL, as shown in Figure 17. MIC26603YJL (Figure 18) compared to MIC26601YJL (Figure 16) highlights the difference in efficiency when load/output current is below 500mA.

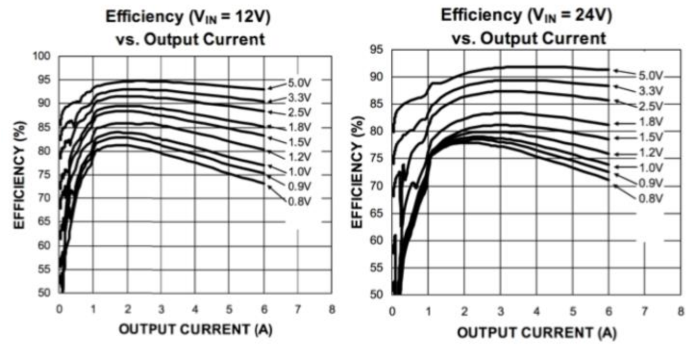


Figure 18. MIC26603YJL Efficiency vs. Load

In M2M applications, the modem is not the only device to be powered; therefore, devices with current higher than 3A peak provide some headroom to power the rest of the application. MIC26903YJL (9A maximum) and MIC261203YJL (12A maximum) provide a pin-to-pin compatible solution for higher current applications. For smaller input ranges of 4.5V minimum up to 19V maximum, MIC24052 (6A maximum), MIC24054 (9A maximum), and MIC24056 (12A maximum) offer pin-to-pin compatibility with the MIC26x03 series.

MIC28510YJL

The MIC28510YJL is structurally similar to the MIC26601YJL. It also features Hyper Speed Control architecture, but it enables a wider input voltage range of 7V up to 75V (please refer to MIC26601YJL section for more details). However, as shown in the evaluation board design, the device needs an external 5V rail to bias the DC-to-DC converter's internal circuit. This circuit can be done with a very small, low cost ballast circuit with a Zener diode and small bipolar transistor. Please refer this part's evaluation board design for more information.

Figure 19 shows how much average current can be supported by the device depending upon the input voltage and the ambient temperature around the device.

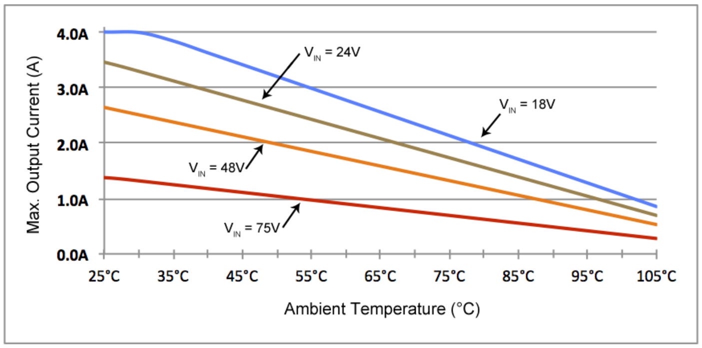


Figure 19. MIC28510YJL Maximum Average Output Current vs. Ambient Temperature

MIC69303YML

The MIC69903YML is a 3A LDO designed with µCap technology which makes it stable with low ESR and low value capacitance, like ceramic capacitors. Enabling high stability with low output capacitance and low ESR optimizes the load regulation by making the loop response fast and stable. This becomes a perfect fit for applications using M2M modules that are under difficult time response constraints with big load variations. The absolute maximum dropout is 500mV over temperature. In order to compensate the first stage voltage error (accuracy, PCB impedance), a safe value is to take 700mV minimum drop between input and output voltage. Moreover and generally speaking, an LDO provides good PSRR only when the dropout voltage is high enough to not saturate the internal pass device. Voltage dropout must be sufficiently high to filter out as much first stage ripple as possible and to ensure optimized load regulation/stability. As shown in Figure 14, the dropout voltage varies between (4.5V-5%)-(3.6V+5%)≈500mV and (5.0V-5%)-(3.6V+5%)≈1.0V.

The maximum average current for the M2M module, according to Table 1, is 800mA. Considering this,

$$T_{AMAX} = T_{JMAX} - (V_{DROPMAX} \times I_{OUTAVGMAX} \times R_{TH})$$

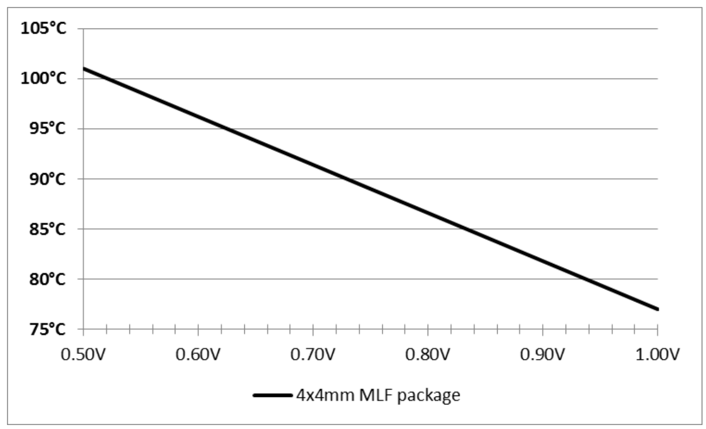


Figure 20. MIC69303YML Maximum Ambient Temperature vs. Dropout

As shown in Figure 20, the MIC69303YML 4mm × 4mm MLF package's power dissipation capability dictates the maximum dropout voltage that it can support. Thus, it drives the MIC69303YML output voltage setting depending upon the input voltage used (4.5V to 5V).

Figure 21 and Figure 22 show the performance graphs of MIC69303YML for:

- Line regulation: Voltage variations on input (the DC-to-DC first stage) will not drive perturbations on M2M power supply.
- Load regulation: Fast loads (burst emissions of the M2M module/end of transmission) will not induce power supply instabilities and ensure a clean power supply for the M2M module.

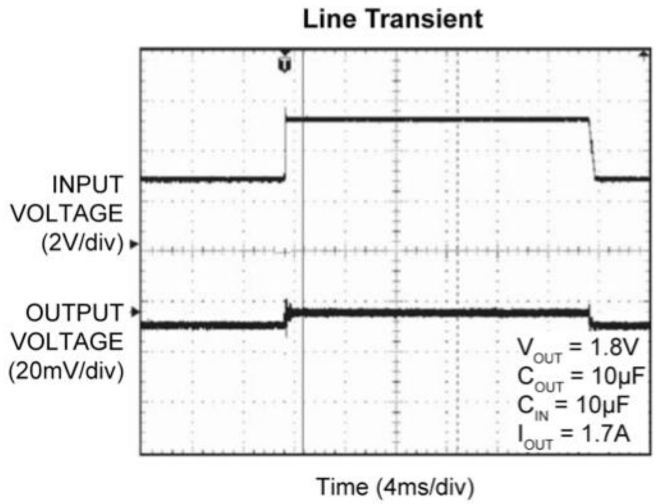


Figure 21. MIC69303YML Line Regulation

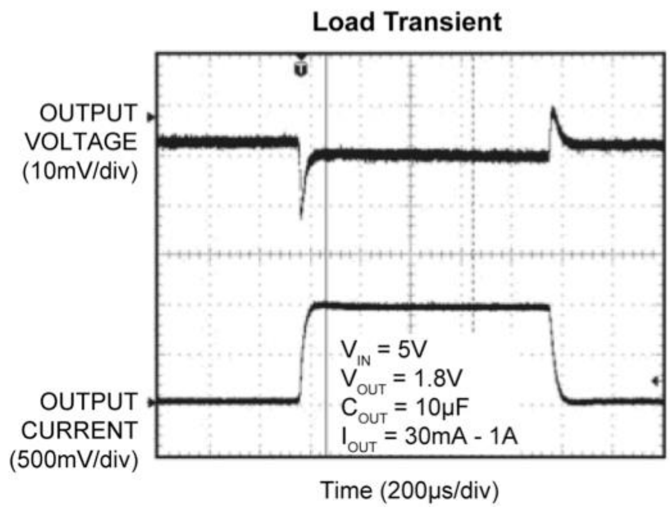


Figure 22. MIC69303YML Load Regulation

MIC38300HYHL

The MIC38300HYHL is part of the Micrel HELDO (High Efficiency LDO) family that provides a fully integrated solution that features a DC-to-DC converter and LDO advantages:

- DC-to-DC converter efficiency (see Figure 25)
- High performance LDO with ultra-fast load and line regulation (see Figure 26 and Figure 27)
- LDO low output noise (see Figure 28)
- LDO low EMI (see Figure 29)

The MIC38300HYHL integrates a DC-to-DC converter and its inductor, which internally feeds an ultra-fast/low-noise LDO regulator (see Figure 23).

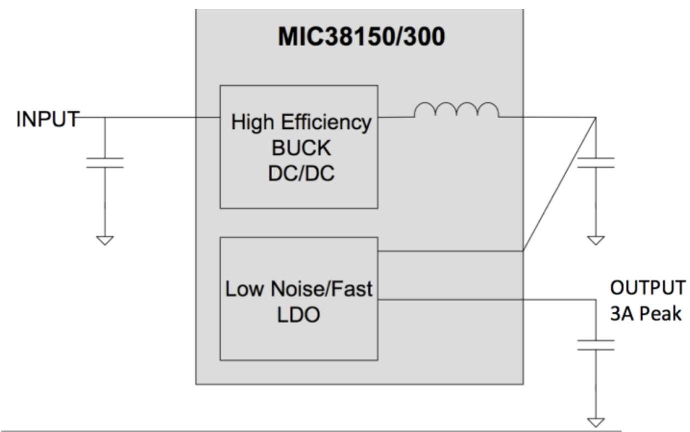


Figure 23. MIC38300HYHL Internal Structure

Structurally, the MIC38300HYHL needs a minimum dropout to ensure fast and stable regulation. The minimum dropout needed over temperature has to be 1.2V. The 4mm × 6mm MLF package has 24°C/W thermal resistance. As shown in Figure 24, MIC38300HYHL can sustain 800mA average current up to +105°C ambient temperature around the IC.

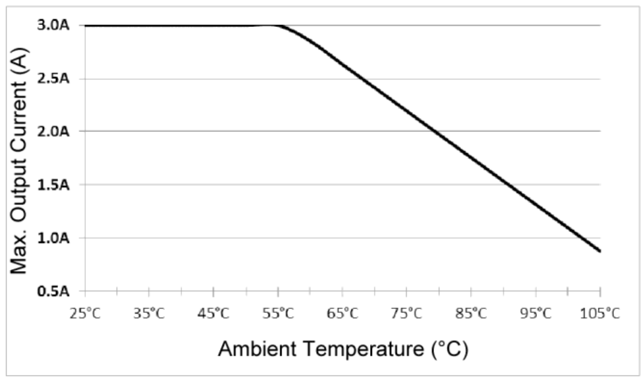


Figure 24. MIC38300HYHL Maximum Output Current vs. Ambient Temperature

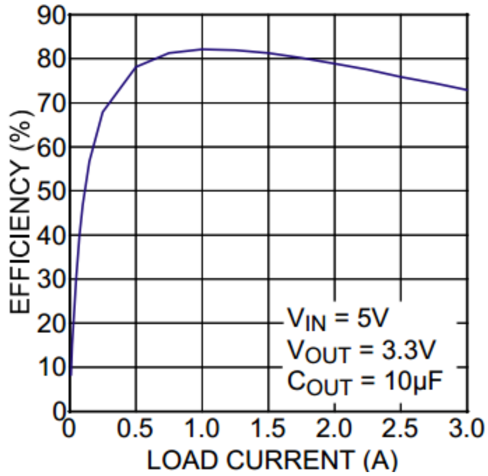


Figure 25. MIC38300HYHL Efficiency vs. Load

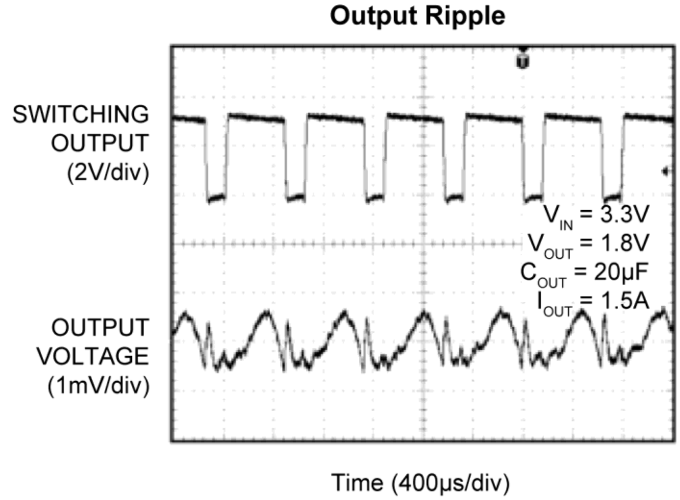


Figure 28. MIC38300HYHL Output Ripple

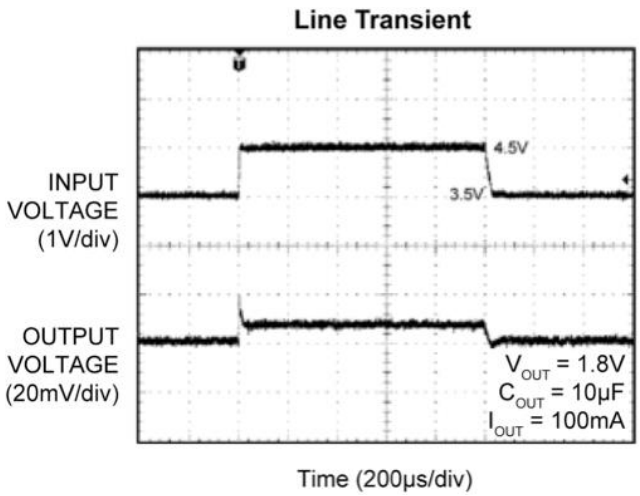


Figure 26. MIC38300HYHL Line Regulation

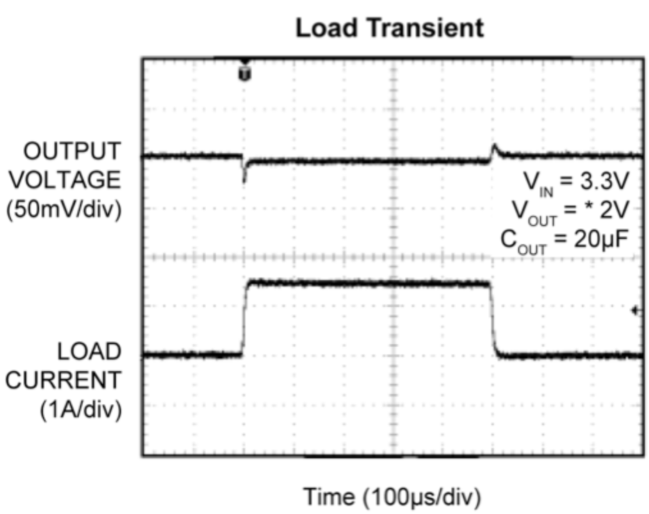
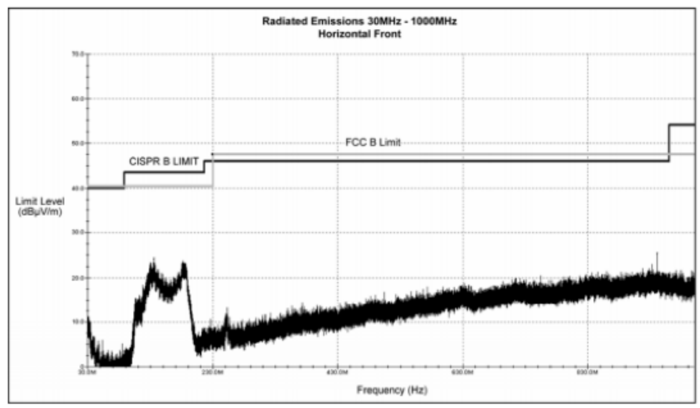
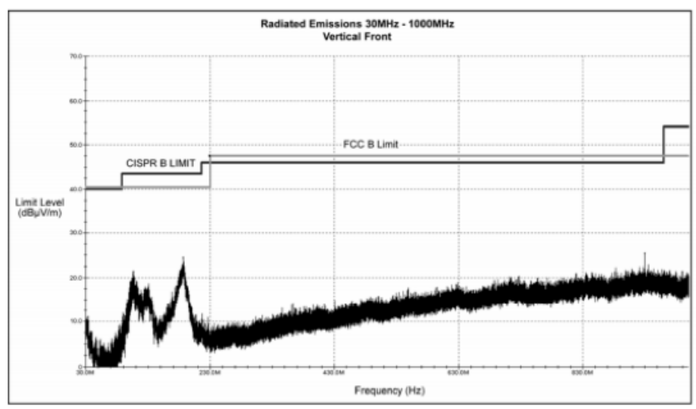


Figure 27. MIC38300HYHL Load Regulation



EMI Test – Horizontal Front



EMI Test – Vertical Front

Figure 29. MIC38300HYHL Emissions (Evaluation Board)

MIC2207YML

The MIC2207YML is a 2MHz asynchronous DC-to-DC converter that features a very fast control loop with internal compensation enabling fast load regulation (Figure 31). The device is highly efficient; typically 93% at 1A load at 25°C (Figure 32). At higher temperatures, the internal MOSFET RDSon also increases and induces greater losses. However, at higher temperatures, the low-side Schottky diode has a lower forward voltage that compensates additional losses on the internal MOSFET. Overall, 93% efficiency at 1A load is an approximation accurate enough for higher temperature operation. As shown in Figure 30, the MIC2207YML can sustain 1.25A average current at +105°C ambient temperature, 2.5A at +85°C, 3A at +55°C. The MIC2207YML fits all types of applications that power a M2M module from a 5V rail.

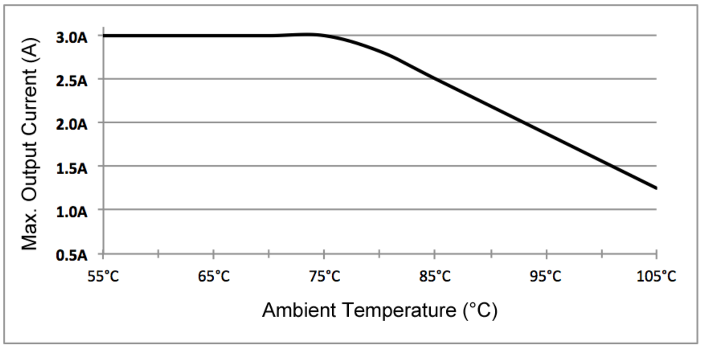


Figure 30. MIC2207YML Maximum Output Current vs. Ambient Temperature

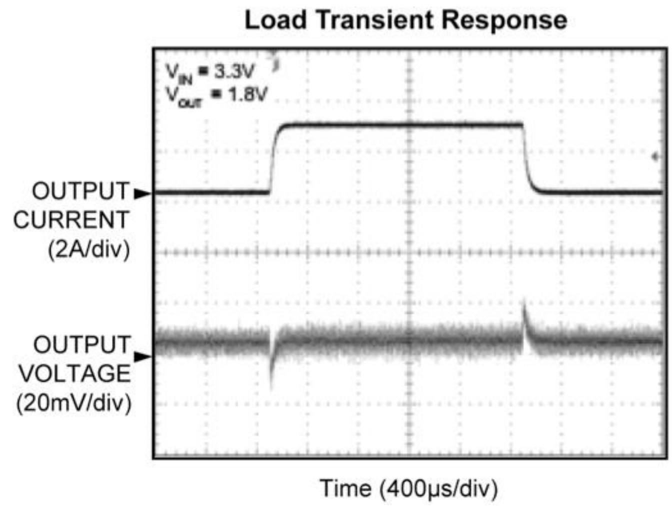


Figure 31. MIC2207YML Load Regulation

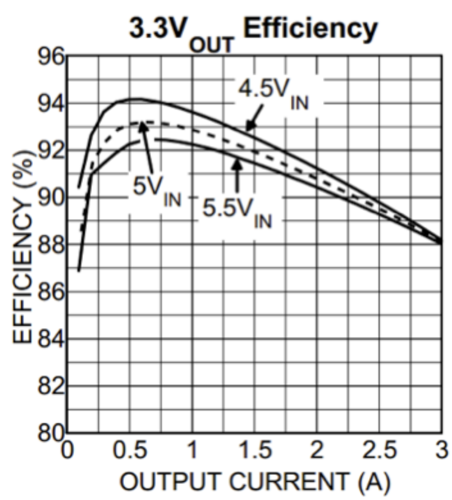


Figure 32. MIC2207YML Efficiency vs. Load

MICREL, INC. 2180 FORTUNE DRIVE SAN JOSE, CA 95131 USA
TEL +1 (408) 944-0800 FAX +1 (408) 474-1000 WEB http://www.micrel.com