Power is Knowledge

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

TW Disti Training

Sep 2022

SMART | CONNECTED | SECURE

Scientia potentia est – Knowledge is power

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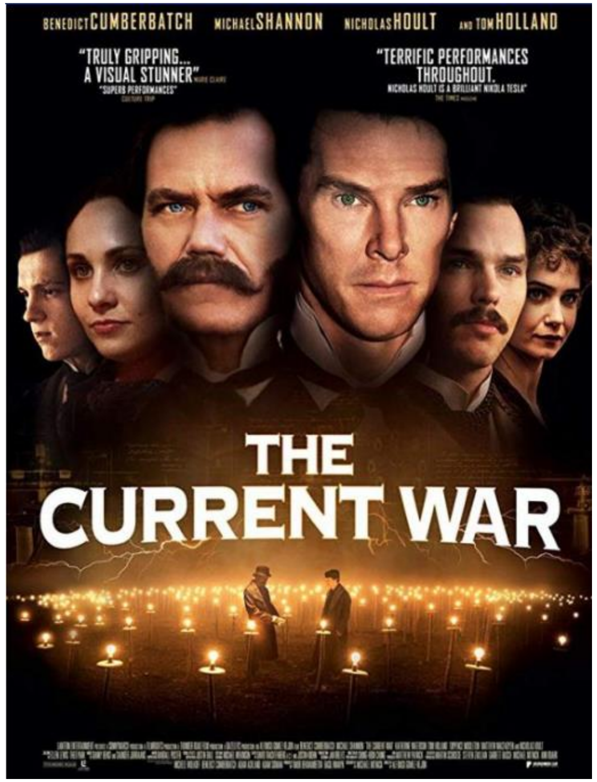
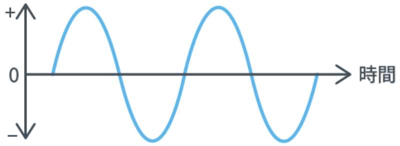
Power is Knowledge (AC ? DC? ADC? DAC?)

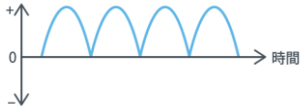
- 沒**知識**也要有**常識**、沒**常識**也要常**看電視**、不**看電視**總也要**看電影** **(電流大戰)**
  - 特斯拉跟愛迪生的恩怨情仇~ 交流/AC與直流/DC的戰爭 (The Current War) Or The **Currency** War?
  - AC(Alternating Current) - 電力遠距離輸送方便，可以將低壓通過升壓變壓器後，升壓到十幾萬伏後輸送到很遠的地方，然後再通過降壓變壓器把高壓將為低壓供給民用、發電量相同條件下，交流電的發電裝置比直流發電裝置要簡單。**然而**大多數用電器都是使用直流電，這需要將交流電經過整流濾波後才能使用。
  - DC(Direct Current) - 不用整流濾波裝置就可以直接使用。**然而**直流電電壓無法通過變壓器進行升壓或降壓。只能通過專門的電子電路進行升壓或降壓變換且在發電量相同條件下，直流發電裝置比交流發電裝置複雜。





Actions Speak Louder than words

- **如何設計一個好的電源供應器?**
  - 自從尼古拉·特斯拉(Nikola Tesla)底定了輸配電的系統為交流電型態之後，將交流高壓電轉變為電子元件適用的直流低電壓，這一功能的產品--電源供應器。就一直存在這世上。時至今日，電源供應器由一開始龐大笨重的線性變壓器，發展為各式各樣拓樸架構的交換式電源供應器，不但縮小了體積，也帶來了更高的效率及可靠性。
  - 傳統的線性變壓器電源，輸出功率與體積及重量成正比，一個10W左右的線性變壓器其重量莫約300g左右，但如果輸出功率提高到100W，則重量將倍增到3~5Kg之譜，這等份量別說是隨身帶出門旅行了，就算是放在家中要移動它，都可以當作是在做重量訓練了。而且如果還需要基本的電壓反饋功能，則還得加裝線性調節器(linear regulator)，而此調節器是以熱損耗的方式將高於規格的電壓降消耗掉，所以為了能控制合理的溫升，則又要再加裝龐大的散熱裝置，使整體電源的體積更加龐大，重量也隨之倍增。所以目前除了在一些音響的發燒友，對輸出漣波雜訊干擾(ripple noise)有極度的要求之外， 幾乎已經沒有線性電源的需求。



Step 1 ~ Spec define

- 我們就以一台在NB使用的120W adapter來舉例，看看各個應該被定義的項目，及大致的參數，這其中包含了輸入電壓及頻率、外觀尺寸、工作溫溼度、輸入AC socket、整體效率、待機功耗、輸出電壓、輸出電流、Peak Load、保護(含OCP/OVP/OTP) 、各項EMC需求，等等...

項目	規格
輸入電壓及頻率	90 ~264Vac (50/60Hz)
外觀尺寸	123*45*67 mm
工作溫溼度	-10℃ ~ 40℃
輸入AC socket	C14
輸出電壓	19V±5%
輸出電流	6.3A
整體效率	Follow DoE level VI & CoC Ver. 5 tier2
待機功耗	0.15W
Peak Load	x 2 (50mS@1sec period)
保護(含OCP/OVP/OTP)	Latch / hiccup
各項EMC需求	IEC62368-1

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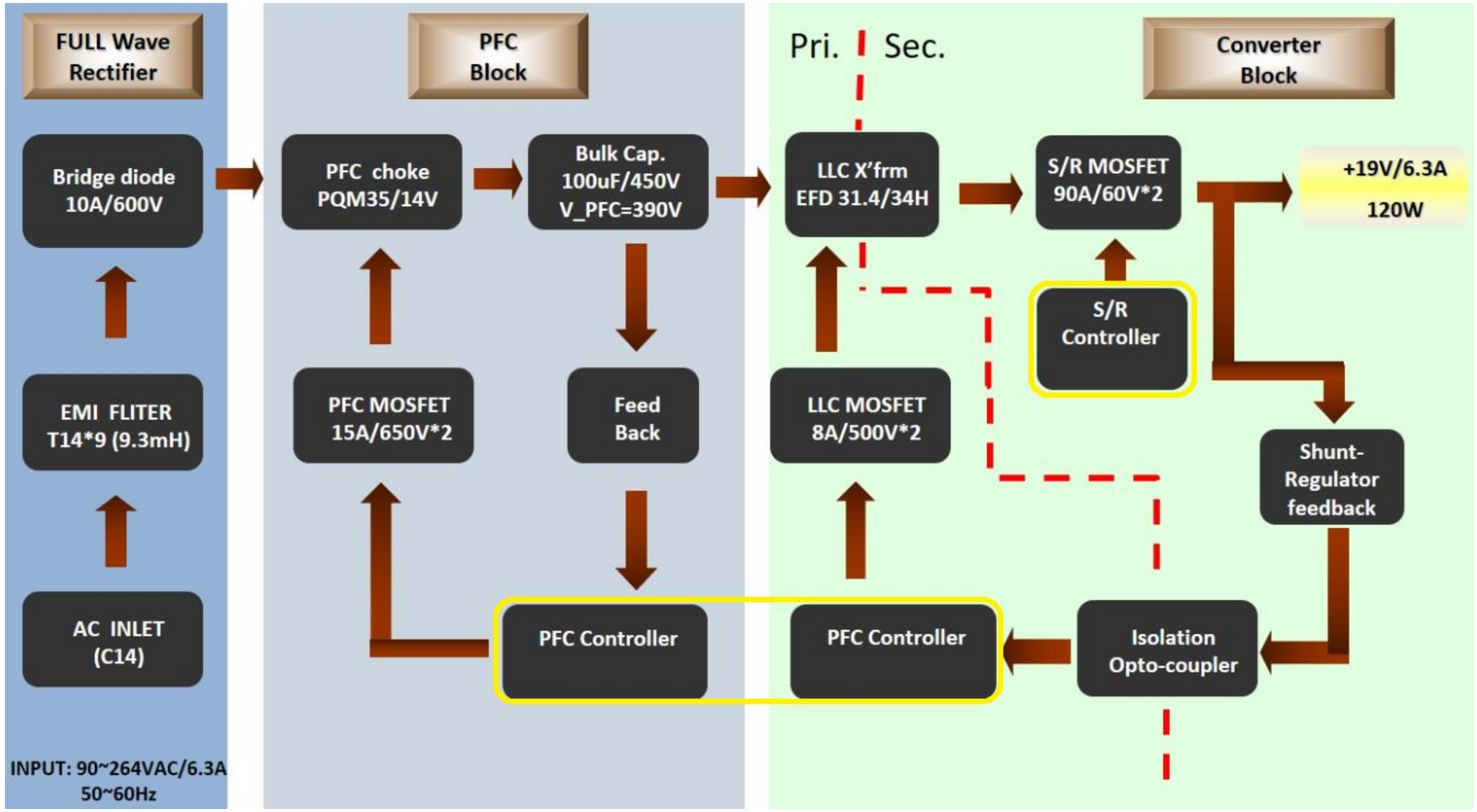
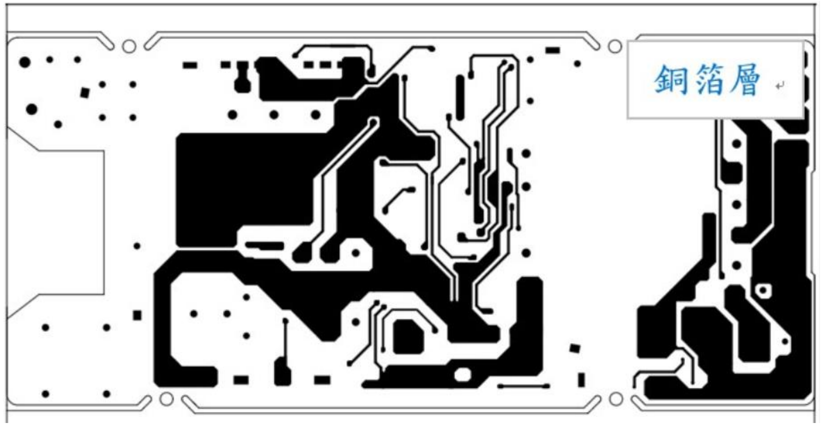
Step 2 ~ Topology decide

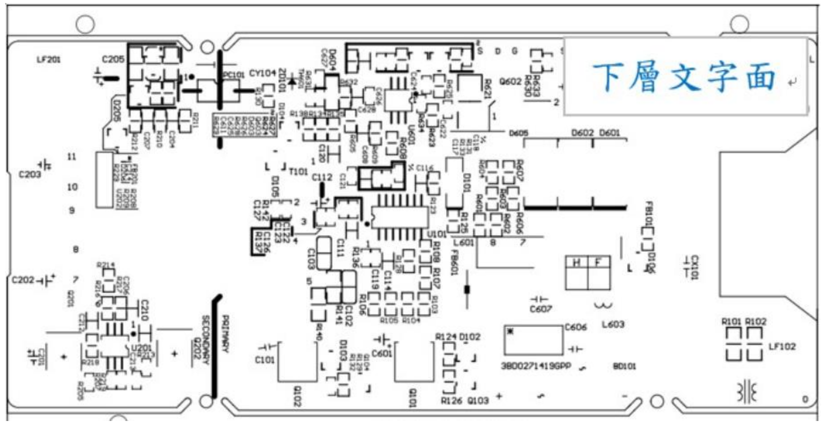
- 可選用的架構一般有Flyback，ACF(active-clamp flyback) 及 HB-LLC 可選擇。但有鑑於日益嚴峻的法規要求，Flyback 效率過低的特性恐不合適，剩下的ACF及HB-LLC雖都可達成，但考量ACF在輕載效率較難調校。故選用HB-LLC為此次的拓樸架構。
- 在選定拓樸架構後，為使設計過程流暢，一般會以方塊圖的方式，大致先區分不同區塊的線路架構，及主要選用的IC或元件名稱。再此因考量輸入功率 >75W，為符合歐盟對於 總諧波失真 (Total harmonic distortion)的需求，需再加入一級 PFC線路。方能滿足歐盟要求。



Step 3 ~ Circuit/Layout/PCB/SMD

- 在線路架構確認，元件選擇完成之後，便進入PCB layout的階段，如何將所有的元件放入客戶指定大小尺寸之中，而且還要兼顧電性，安規距離，降低生產組裝困難度，生產自動化，熱對流，等等條件，這就需要一名專業的layout 工程師搭配合適的軟體來完成，單以此例120W的adapter來說，一名有經驗的layout工程師莫約需要1週的時間方能由無至有的完成初版的PCB。
- 完成的PCB檔案接著便該送往專門製樣的PCB廠商那邊安排生產樣品了，正常來說，大約3~5工作日再加上USD $200左右的樣製費就可以拿到10~15 pcs PCB樣品了，自行設計的玩家為了節省經費，當然可以嘗試以自行購買的帶銅箔的PCB裸板進行蝕刻水洗，但考量精度不高，銅線容易斷裂，且成品僅僅只有銅箔層，而無上/下層文字面可供插件參考，更別說還是得購買一堆化學蝕刻液體，然後還要挑戰精確的將PCB上的貫通孔逐一的鑽出來，在節省經費不多，但失敗率極高的情形下，並不推薦自行製作PCB。
- 當PCB完成後，便要將前期已經先準備好的，所有BOM表中的元件，手工一一焊接組裝至PCB上，組裝順序一般是以先SMD 後DIP，先小元件，後大元件的方式進行組裝。





Step 4 ~ Functional test/Fine Tune/Assembly

- 最終由製樣至開機完成的時間至少也得再花費1週的時間。這都還不算入所有BOM表中的元件前期備料的時間。在這個階段自行設計的玩家如果只製作一台樣機，反而是比較快的，但前提是不計入前期備料的時間及成本，因為個人玩家不比公司行號，能拿到的資源有限，所有的元件都得一顆顆到電子材料行採買，一台樣機的所有材料準備好，絕對是比買一顆電源成品還要高出2~3倍。
- 完成開機步驟之後便正式進入了電性驗證及調校的階段。又為了模擬各國的電力系統，及各式各樣負載條件，所以需要許多相關儀器設備來完成電性驗證: 可程式化AC電源供應器，以及模擬電子負載，當然高精度的示波器及相關探棒(電壓探棒/電流探棒/差動探棒)，數位電錶，功率計，溫控烙鐵，自然也不可少，再某些情況下需要確認線路上的小訊號，則DC直流電源供應器也是必要裝備，如此下來光儀器就已不是一般玩家負擔的起的了，若要再進階一些為求回授穩定性高，相位邊限(Phase Margin)、增益邊限(Gain Margin)足夠，一套上百萬台幣的頻率響應分析儀也是必要的設備。
- 自行設計的玩家一般不會有完整的測試儀器設備，所以在初版樣品開機後，就只能以簡易的三用電表確認電壓無誤，好一點的可能有負載電阻可以進行基本的老化及溫昇測試，但如果沒有較精良的設備，遇到較困難的問題，可能就此卡住，而無法進一步驗證。即便正常開機，但穩定性及壽命，也仍是未知之天。但話說回來，如果一切過程都沒問題，或問題能被排解，但憑一己之力獨自完成一個電源，即便付出比直接購買一顆市售的電源，更高的成本，以及更多的心力。也是值得的。因為成就感—無價。

Conclusion

- 經過上述的過程大 … 有的各主要階段，
  當然這其中仍有許 … 波形及測試數據的
  確認，替代料的驗 … 調校，等等...都對電
  源設計的難度再添
- 若回到個人設計電 … 高的費用之外，還
  得親力親為的由規 … 圖數設計/線路繪製
  /PCB layout/材料採 … 的問題之外，還需
  耗費大量的時間及 … ，還需要有相當的”
  熱忱”，且這還不 … 進行電性驗證，及錯
  綜複雜的品質驗證 … 看來電源DIY並不是
  一項高性價比的好 … 的一種挑戰吧。

MICROCHIP

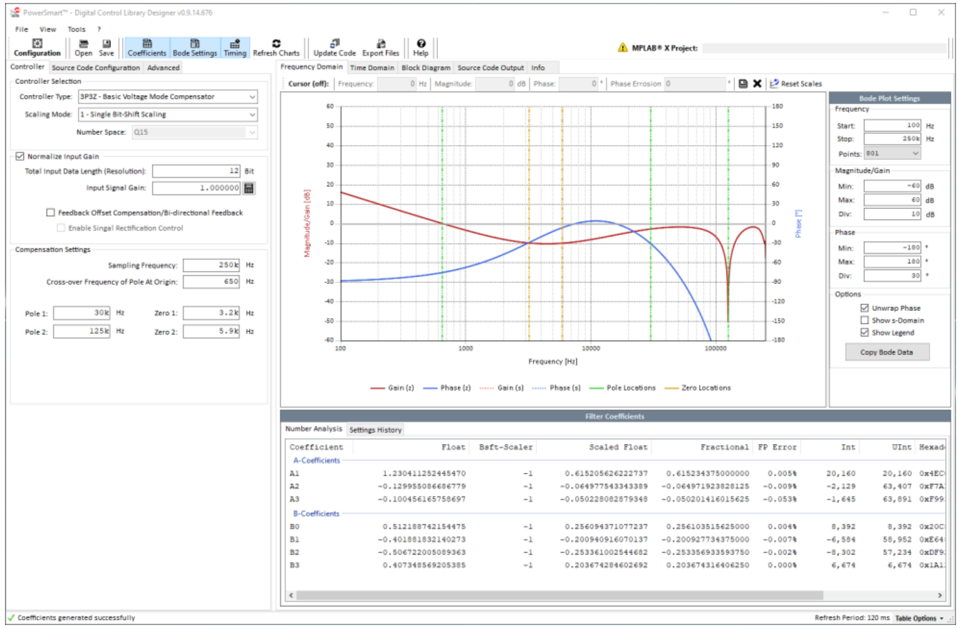
PowerSmart™ Design Suite

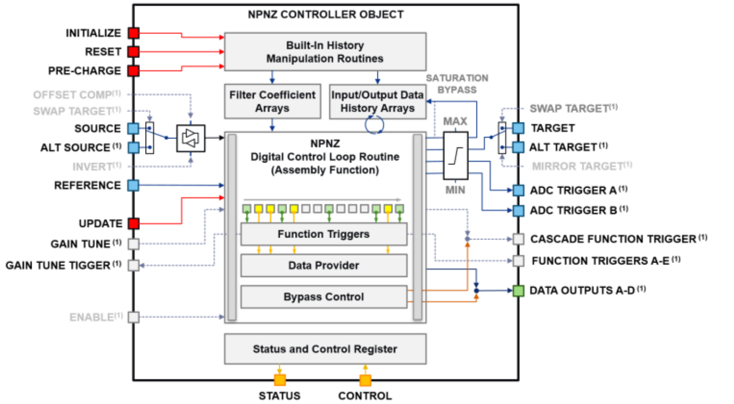
Design Tools

PowerSmart™ Development Suite

The Fast Way to a Working Power Supply

- **Create MPLAB X project**
  - Select device, compiler version, etc.
- **Configure device using MCC GUI**
  - Adds main.c to project, setup clocks and dividers
  - Configure ADC channel, pins, trigger source, interrupts
  - Configure PWMs including when to trigger ADC
- **Add example code snippets**
  - State machine, timing loop and soft start
- **Create P-Term loop measurement code using PowerSmart DCLD**
  - Use GUI to configure source code such as anti-windup clamping
- **Measure poles & zeros of plant**
- **Use PowerSmart DCLD to generate final compensator assembly code**



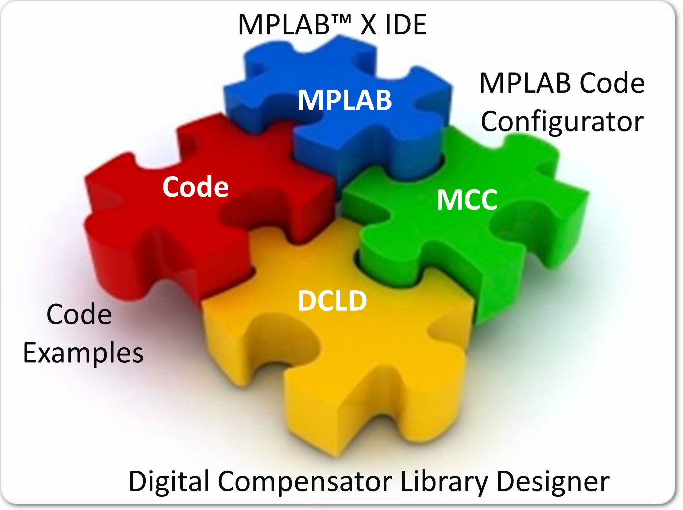


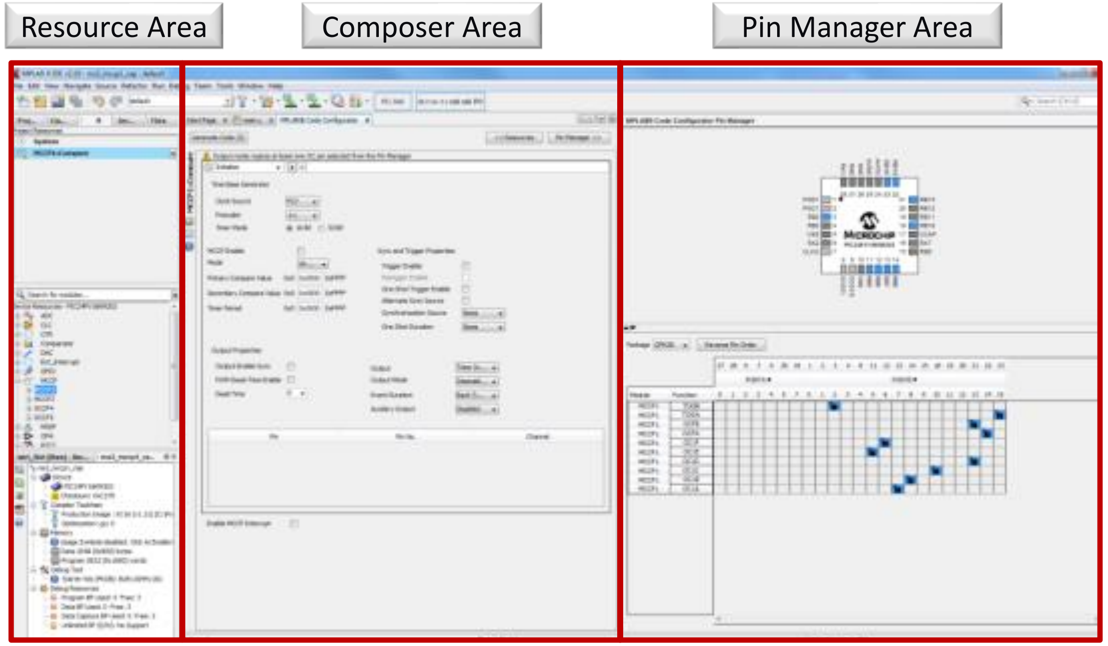
MPLAB® Code Configurator (MCC)

Use with PowerSmart Development Suite

Graphical programming environment that generates easy-to-understand code

- **Automatic configuration of peripherals**
  - Reduces overall design effort
  - Minimizes references to product datasheet
- **Intuitive interface for quick start**



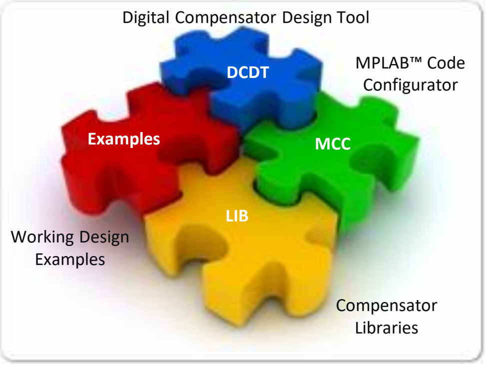


Digital Power Design Examples

Speed Development / Reduce Risk

Royalty-free microcontroller and application-specific hardware and software designs

- Starter kits
- Development boards / EVBs
- Reference designs
- Code examples
- Application notes




```
_AltRegContext2Setup:

CTXTSWP #0x2   ; Swap to Alternate W-Reg #2

 ; w0 register used for compensator control reference

 mov #ADCBUF3,  w1   ; Address of ADCBUF3 register
 mov #CMP2DAC,  w2   ; Address of CMP2DAC register

 ; w3-w5 used for ACCAx and MAC/MPY instructions

 mov #BOOST_COMP_2P2Z_POSTSCALER, w6
 mov #BOOST_COMP_2P2Z_POSTSHIFT,     w7
 mov #_boostOptions,                          w8
 mov #_boostABCoefficients,                   w9
 mov #_boostErrorControlHistory,              w10
 mov #BOOST_COMP_2P2Z_MIN_CLAMP,    w11
 mov #BOOST_COMP_2P2Z_MAX_CLAMP,    w12

CTXTSWP #0x0  ; Swap back to main register set

return
```

MPLAB® Starter Kit for Digital Power -3

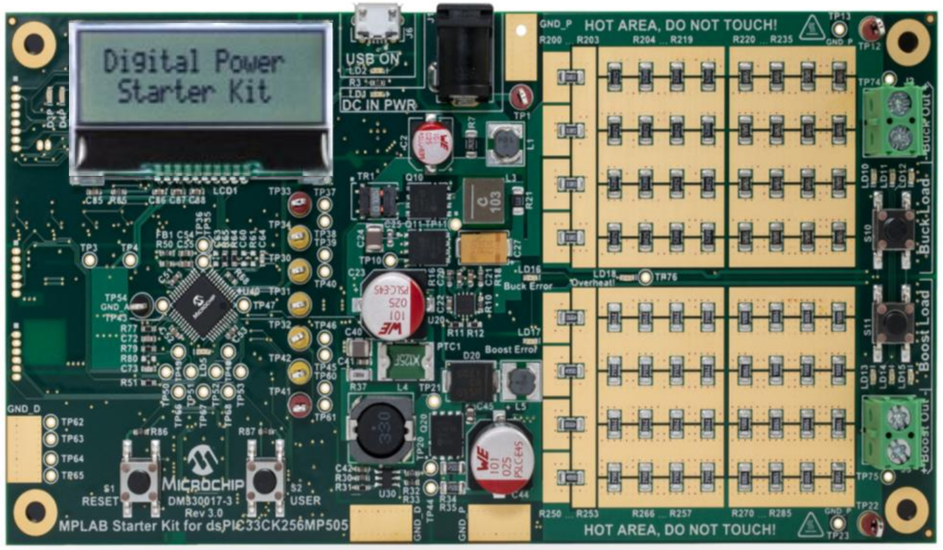
Features:

- dsPIC33CK256MP based
- Independent buck and boost DC/DC converters
- LCD display, status LEDs, temperature sensors
- Configurable resistive loads
- PKOB-4 On-board debugging / programming via USB

Package Contents:

- Board (~ 5” x 2.5”)
- Mini USB cable
- 9V Power Supply
- Info Sheet with schematic

$199.99



Order # DM330017-3

Digital Power PIMs

- **Building blocks for Microchip's digital power development boards**
  - Controller easily swapped out for evaluation of various dsPIC33 family members

- **Flexibility for prototyping with PCBs that use this standardized DP PIM connector**

- **Features**
  - ICSP™ programming header
  - On-board LDO with Power Good (PG) function
  - Micro USB connector
  - MCP2221A USB to UART/I2C serial converter
  - Edge connection for analog inputs/outputs, PWM outputs and GPIO ports
  - Test point loop for DAC output

Available DP PIMs	Part Number
dsPIC33EP128GS808	MA330043
dsPIC33CK256MP508	MA330048
dsPIC33CH512MP508	MA330049

Available today @ $49 each

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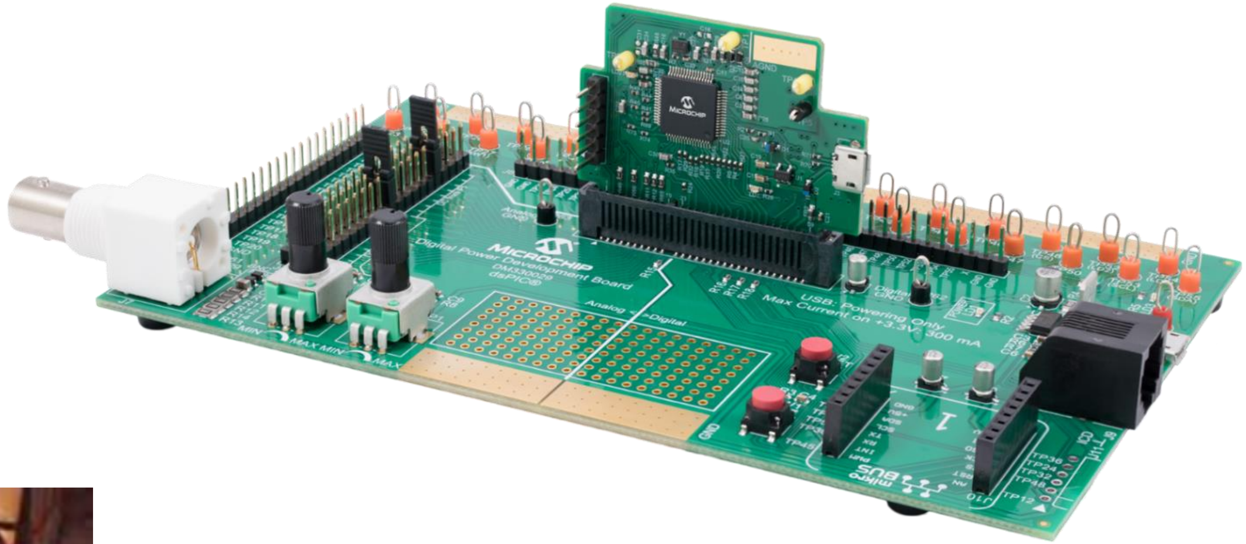
Digital Power Development Board

- Uses new Digital Power PIMs
- Micro Elektronika mikro BUS Socket
- PWM & GPIO Test pins
- Analog Input test pins
- BNC Connector
- Analog potentiometers
- Push button
- Solder pad- Scope ground connection
- Prototyping field (2.54mm raster)



Part Number: DM330029 $112

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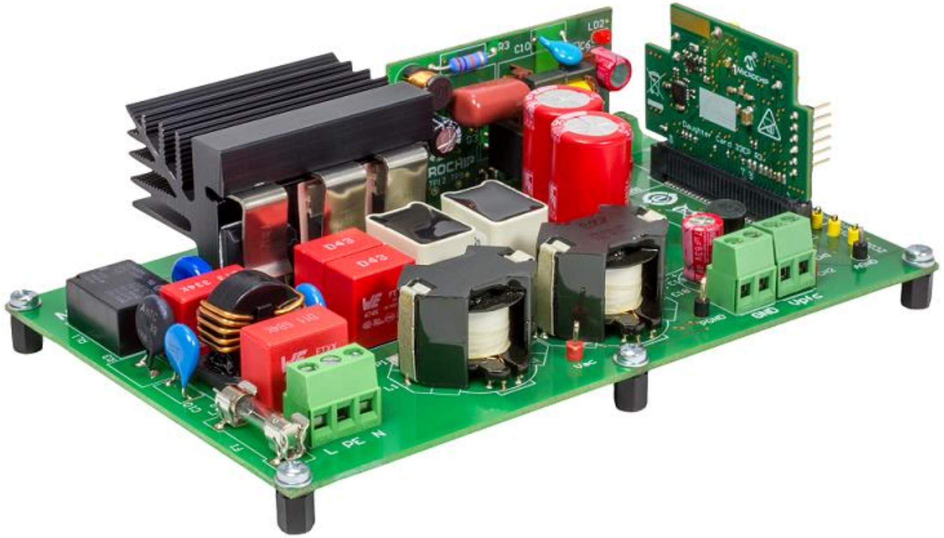
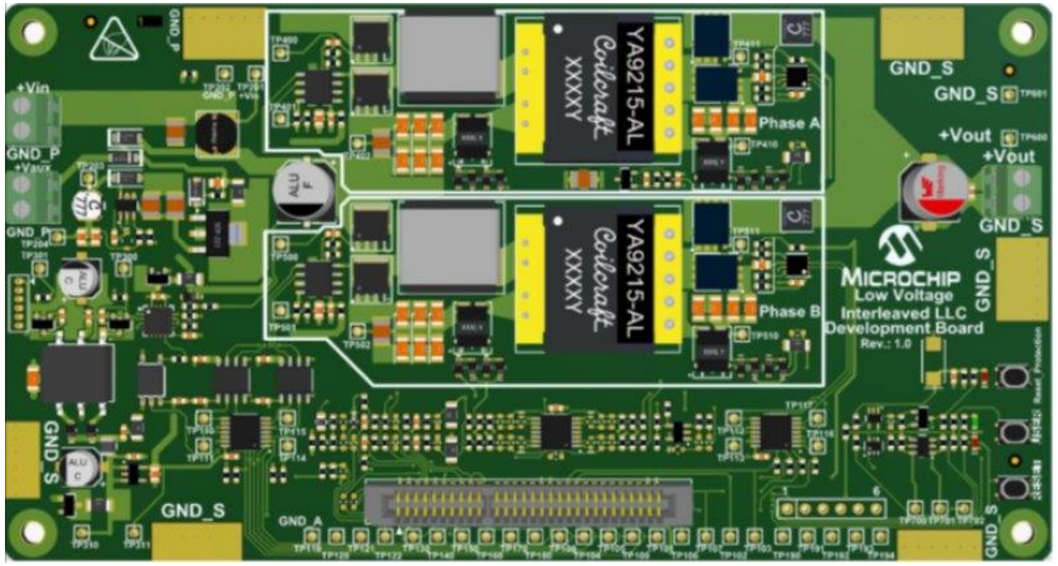
LV PFC Development Board



- **Low Voltage PFC**
  - Vin: 12 - 24V AC
  - Vout: 31 - 42V DC
  - ~50W Max
- **Topology**
  - Single phase or
    Interleaved dual phase
  - Firmware for:
    - Continuous Conduction Mode
    - Critical Conduction Mode (a.k.a. Transition Mode or Boundary Mode)
- **Uses DP PIM controller modules**
- **Companion DC/DC Interleaved LLC Development Board Available Soon**
- **Part # DV330101 $375**

LV ILLC Development Board

- Input working voltage range: 38 - 42 VDC
- Max. Output Power: 30W per phase
- Maximum Switching Frequency: 1000 kHz
- Test Points for outer loop measurements
- Protection circuitry
- HMI Interface (Push buttons and two LEDs)
- AUX Connector
- Supports UART communication, GPIO, Analog input, DAC signal output and 3.3V analog AUX supply
- Uses DP PIM controller modules
- Companion LV PFC Development Board also available
- Part # EV84C64A (available soon)



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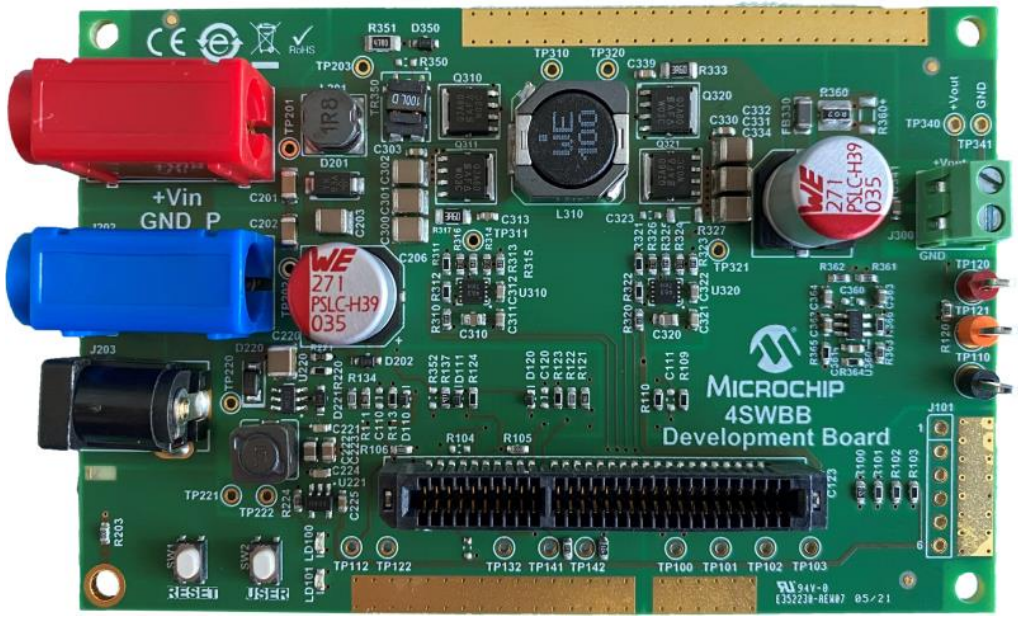
Four-Switch Buck-Boost Development Board

- **Input Working Voltage Range: 8 - 18 VDC**
- **Max. Output Power: 20W**
- **Four-switch power converter with gate drivers:**
  - Left Leg-Buck, Right Leg-Boost
- **Output current shunt amplifier**
- **Test points for outer loop measurements**
- **HMI interface (push buttons and two LEDs)**
- **dsPIC33-DSC DP-PIM socket with test points at the edge of the board**
- **Input filter, overvoltage protection, output filter**
- **Uses DP PIM controller modules**
- **Part # EV44M28A (available soon)**

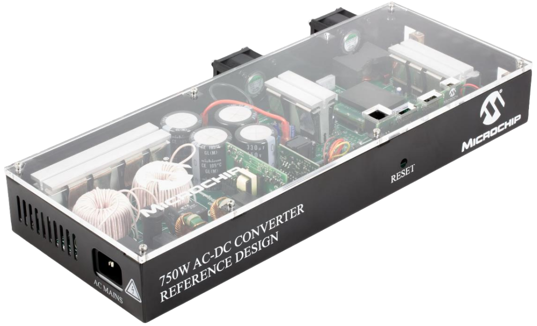


MICROCHIP

Royalty-Free* Reference Designs

Available Today

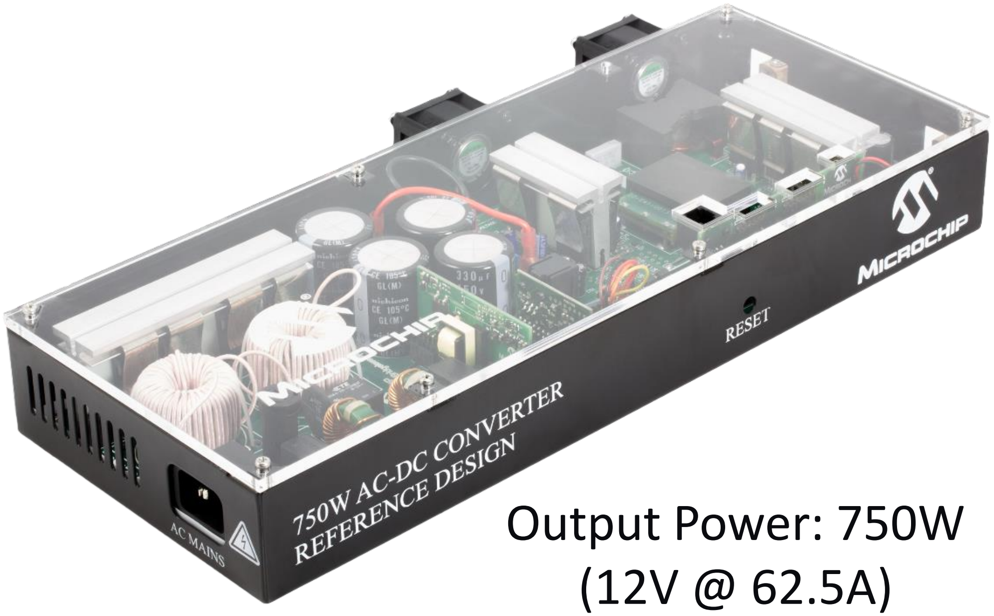
- 750W AC/DC Supply
  - *Semi-Bridgeless PFC*
  - *Zero Voltage Switching Full-Bridge with Peak Current Mode Control using Digital Slope Compensation and Synchronous Rectification*
- 720W Platinum-rated AC/DC Supply
  - *IPFC + interleaved 2-switch forward conv with SR*
  - *Adaptive algorithms to achieve > 94% efficiency*
- Enhanced Solar Micro Inverter
  - *250W panel input, grid-tied output*
  - *MPPT to achieve 94.5% efficiency (peak)*
- 1KW Pure Sine Wave UPS
  - *Offline UPS system*
  - *Push-pull converter & full-bridge inverter*
- Interleaved Power Factor Correction
  - *Two phase interleaved PFC*
  - *Up to 400VDC output, 350W sustained*
- DC/DC LLC Resonant Converter
  - *Zero Voltage Switching on half-bridge conv*
  - *Zero Current Switching on synch rectifier. >95% eff*
- Quarter Brick DC/DC Converter
  - *Phase-shifted full-bridge topology*
  - *Planar magnetics and non-linear control for efficiency*



*Royalty-free when used in accordance with Microchip's licensing agreement

ZVS FB Peak Current Mode 750W AC/DC Ref Design

- Topology
  - Semi-Bridgeless PFC
  - Zero Voltage Switching Full-Bridge with Peak Current Mode Control using Slope Compensation and Synchronous Rectification
- Advanced algorithms
  - Variable bulk voltage
  - Variable switching frequency
  - Non-linear control
- PWM frequency jitter routine to improve EMI
- Active inrush control
- Live Update
- Communication (UART, I2C)



Output Power: 750W
(12V @ 62.5A)

- dsPIC33CK-based Phase-shift full bridge with peak current mode control version of this design is in development

Automotive Digital Power Applications

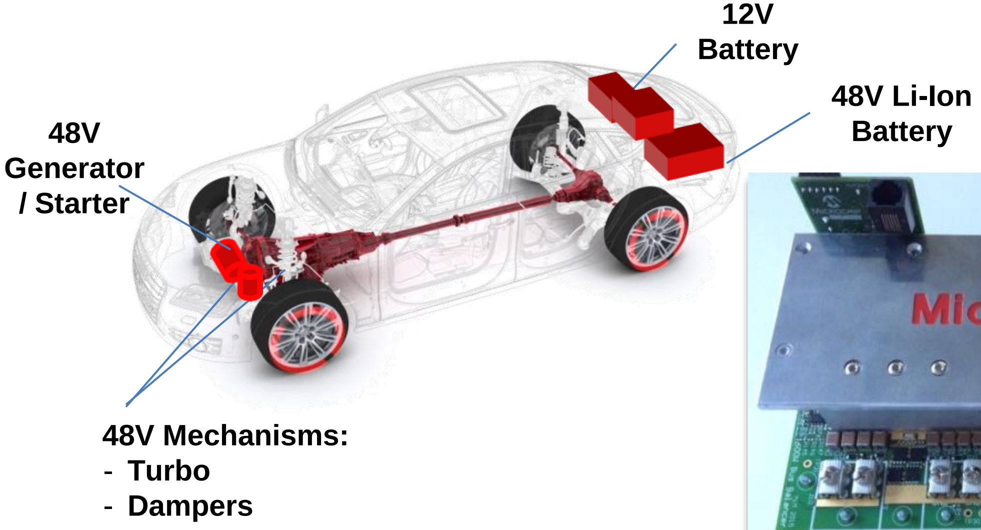
DC – DC Bus Converter

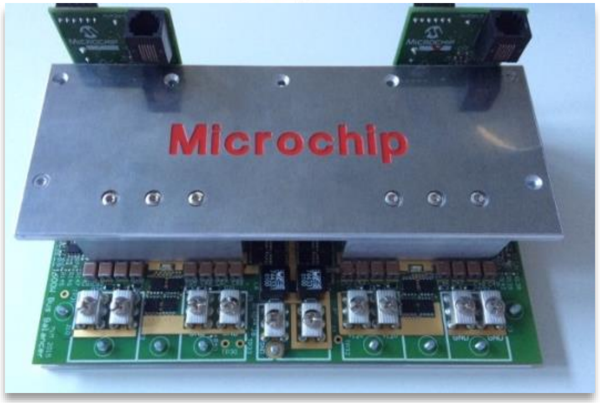
Microchip Components:

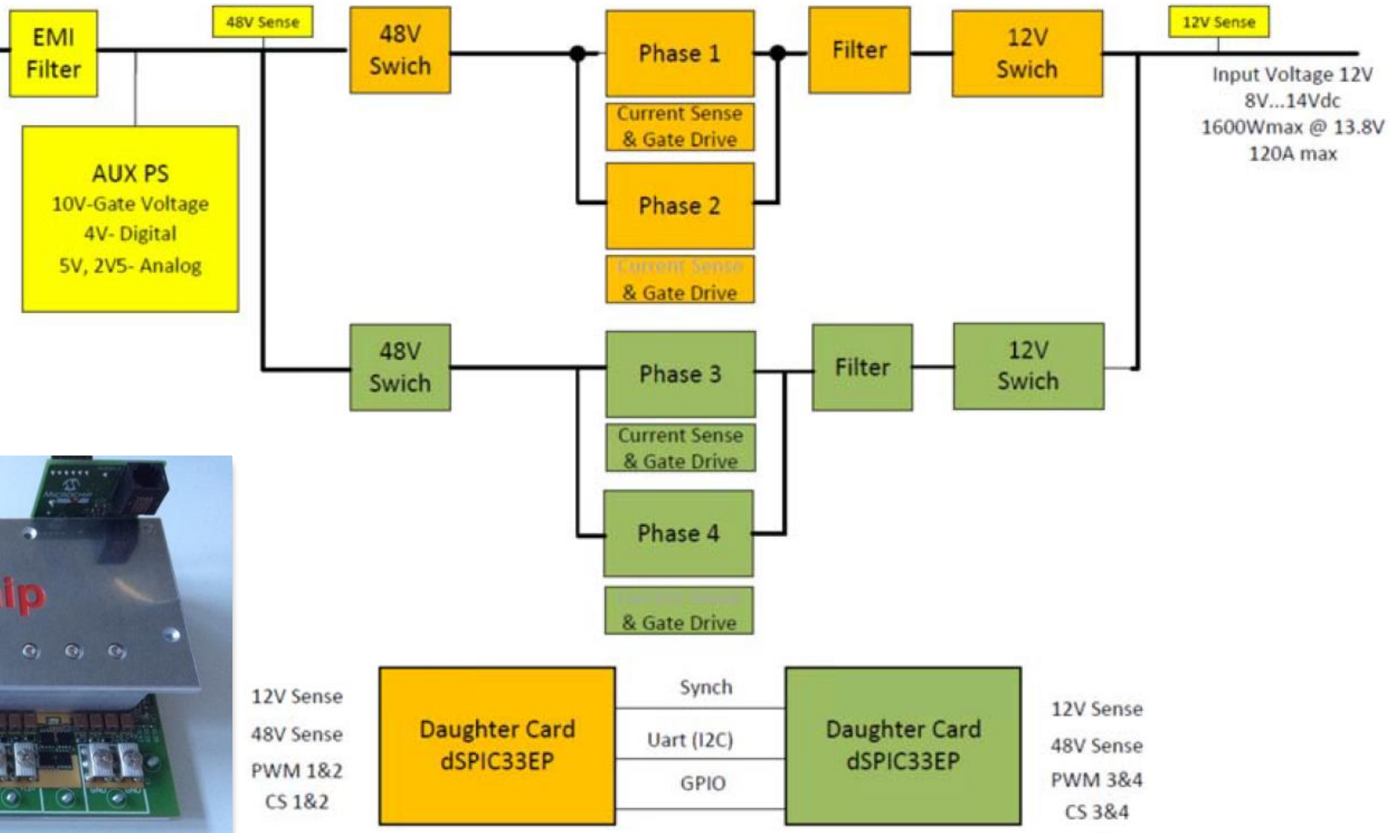
Digital Signal Controllers	dsPIC33EP64GS506
FET Driver Dual Non-inverting	MIC4104YM
Switcher Buck 2V to 15V	MCP16301T-E/CH
Switcher Buck 2V to 24V	MCP16331T-E/CH
VREF 2.5V	MCP1525T-I/TT
LDO 5V	MCP1804T-5002I/OT
FET Driver Single-Non-Inverting	MCP1402T-E/OT
Temperature Sensor	MCP9700T-E/TT
OpAmp 1-Ch 2.8MHz	MCP601T-I/OT

1600W DC-DC Bus Converter 48V <-> 12V

- Four-phase synchronous buck topology
- Non isolated DC/DC converter
- Controllers: 2 x dsPIC33EP64GS506
- Switching frequency equivalent: 348kHz
- Reverse bias protection on both rails
- Dimensions: 188 x 127 x 40mm





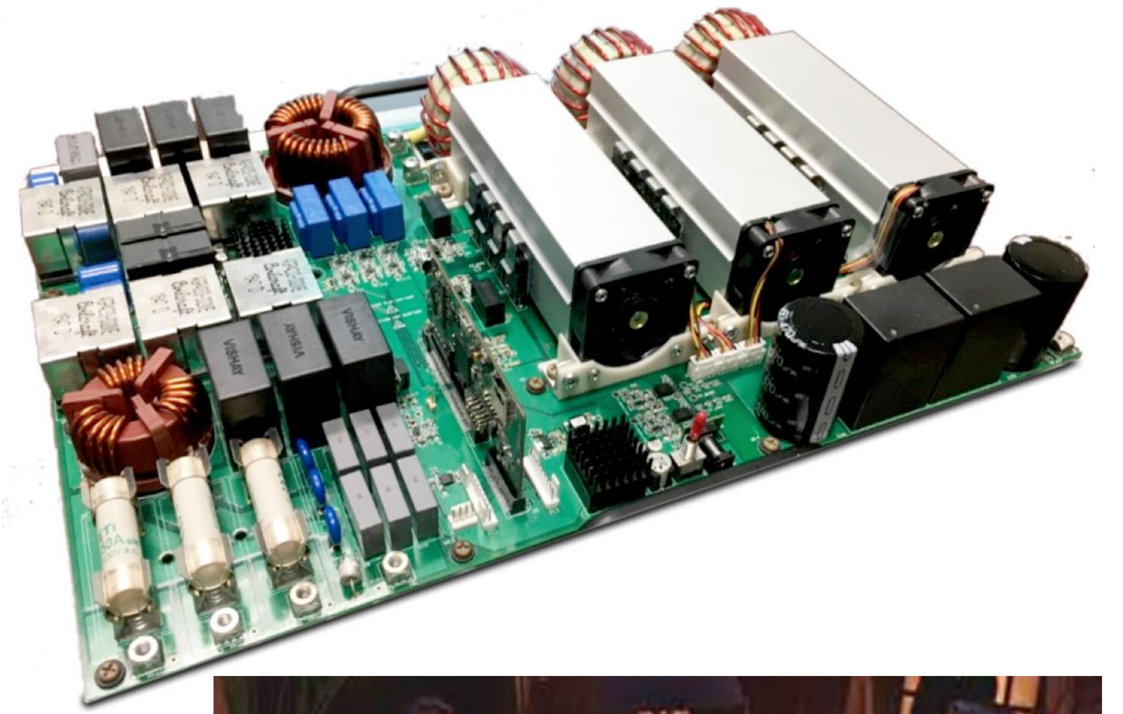


MICROCHIP

Vienna PFC Reference Design

The primary stage of a High-speed EV Charger

- 30 kW Vienna rectifier topology
- 98.5 % peak efficiency
- 3-phase 380/400 VAC, 50 Hz/60 Hz input voltage
- <5 % current THD at half and full loads
- Microchip 700 V, 15 mOhm SiC MOSFETs mounted on AVVID MaxClip heat sinks to reduce communication loop inductance and voltage spikes across devices
- PCB design according to IEC standards, with consideration for safety, current stress, mechanical stress, and noise immunity
- dsPIC33CH controller with verified open-source software using 3-level modulation for digital control



Thank You