DRV8x Products Deep Diving
DRV8x系列產品之深度解析

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TI Spins Motors

TEXAS INSTRUMENTS

Smarter. Safer. Greener.

What Can DRV8x Do?
DRV8x 可實現什麼？

Stepper Motor Driver

步進馬達驅動

- 1.8V~60V; 0~12A
- High Count μ-Stepping Indexer 高細分微步進索引
- Current Regulation / Control 電流調節/控制

Open Loop Control
開放迴路控制

Brushed DC Motor Driver

有刷 DC 馬達驅動

- 1.8V~60V; 0~24A
- Inrush Current / Stall protection 突波電流 / 堵轉保護

Simplicity & Low Cost
易設計，低成本

3-Phase BLDC Motor Driver
三相 BLDC 馬達驅動

- 8V~60V; 0~13A
- Integrated current sense amps / buck 整合電流感應放大器/降壓
- Pre-drivers & drivers (w/ integrated FETs) 門級驅動器/整合MOSFET

Reliability & Efficiency
可靠、高效

Selective Disclosure

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DRV8x Family Feature Intro
DRV8x系列產品特性介紹

Reduced Board Space/減少電路板空間

- Up to 20x smaller than discrete solutions!
- 比離散解決方案少 20 倍的面積！
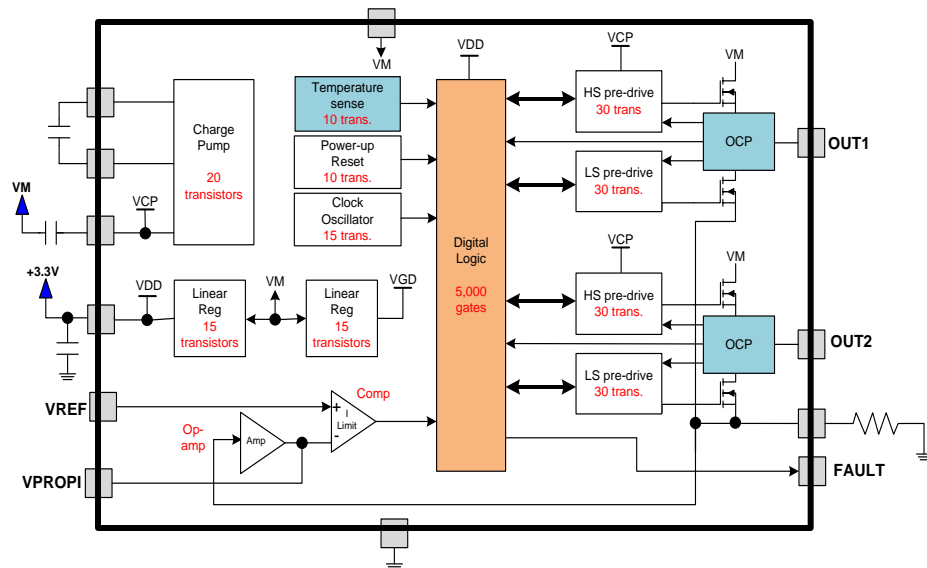
Fully Protected/全面保護

- Short Circuit, Over Current, Thermal, UVLO…
- 短路/過電流/過熱保護、欠壓封鎖

Embedded Intelligence/嵌入式智能

- Ultra efficient architectures help you minimize MCU support！
- 超高效的系統架構將MCU所需支援降至最低！

Drop in and Spin/即插即轉

- EVM requires NO discrete design experience → quicker time to market!
- EVM 無需離散設計經驗→加速產品的上市時程！

How to SelectYourDRV8x:
By Motor Type:
- Stepper, Brushed DC, BLDC, Solenoid/Relay

By Power Source/Current Capability:
- Line-powered, Battery-powered

By Feature:
- Motion profile, Current regulation, Sleep mode, Thermal performance, Form factor…
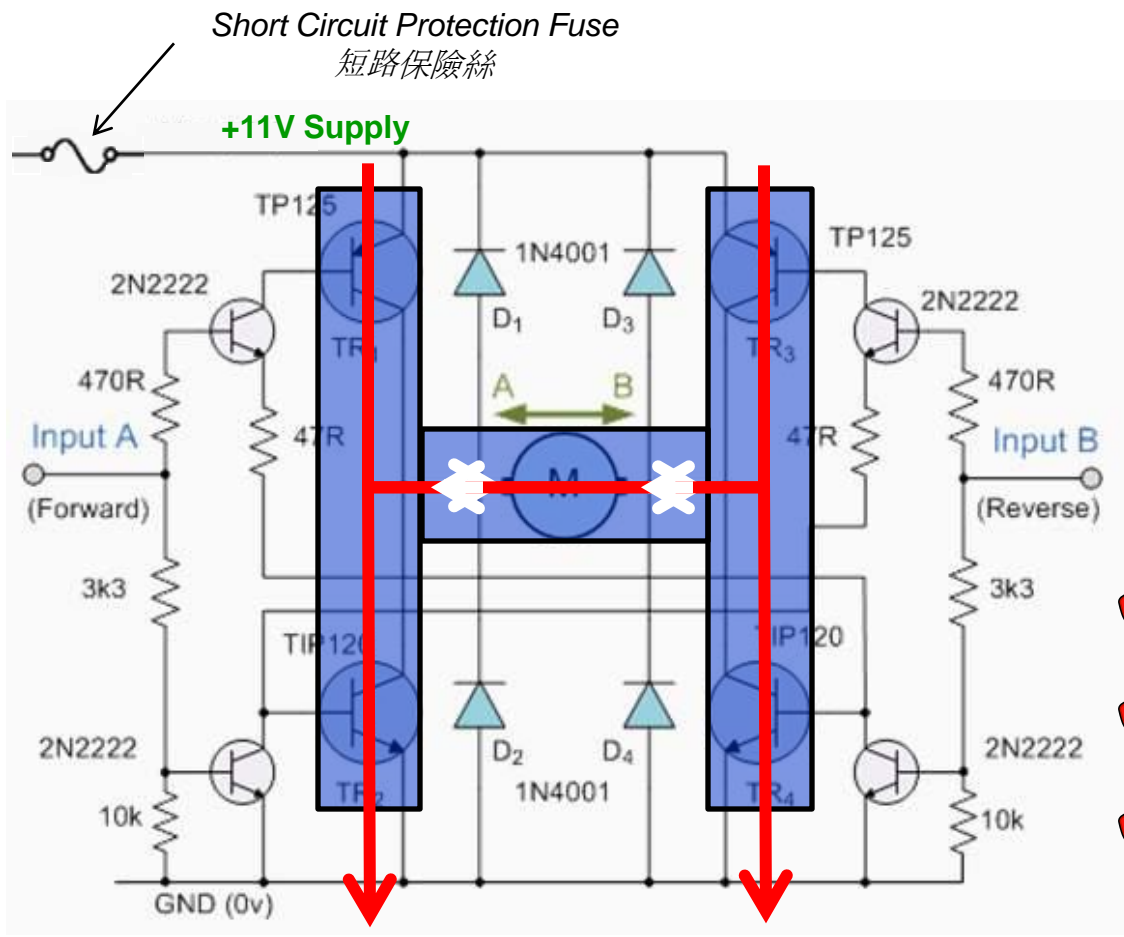
如何選擇適合您的 **DRV8x:**
根據馬達類型:
- 步進馬達、有刷 DC、BLDC、電磁/繼電器

根據供電類型/電流量:
- 電源供電、電池供電

根據特性:
- 動態分析、電流調節、休眠模式、熱效能、尺寸大小…

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DRV8x V.S. Discretes/DRV8x 系列 V.S. 離散元件

Short Circuit Protection Fuse
短路保險絲

+11V Supply

Discrete H-Bridge Motor Driver
離散 H 橋接馬達驅動器

DRV8x: Drop in and Spin!
DRV8x：即插即轉！

Eight motor drivers for stepper, brushed DC motors

Motor Drivers DRV8x

> 60% lower R$_{DS(ON)}$ than previous generation

✓ *Smaller /更小*

✓ *Better Performance / 效能更好*

✓ *Thermal & Short Circuit Protection/過熱 & 短路保護*

✓ *Shoot-Through Protection /擊穿保護*

✓ *UVLO & ESD Protection /欠壓封鎖及ESD保護*

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What will be introduced next are…
接下來將介紹…

- ## DRV8818
  - 2.5A Stepper Driver
- ## DRV8837 **New!!**
  - 1.8A Low Voltage Brushed DC Driver
- ## DRV8844 **New!!**
  - 2.5A Half Bridge Driver

- ## DRV8818
  - 2.5A 步進馬達驅動器
- ## DRV8837 **新品上市!!**
  - 1.8A 低電壓直流有刷馬達驅動器
- ## DRV8844 **新品上市!!**
  - 2.5A 半橋驅動器

And… DRV8x operation philosophy
以及… DRV8x系列產品的操作原理

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DRV8818 – 2.5A Stepper Motor Driver (with On-Chip 1/8 μ-Stepping Indexer)
DRV8818 – 2.5A 步進馬達驅動器（內建整合 1/8 細分索引）

Features

- Dual H-Bridge stepper motor driver
  - Supply voltage: 8~35V
  - Output current: 1.75A RMS / 2.5A peak per winding

- P2P upgrade to DRV8811 with lower Rdson (0.37Ω HS+LS)

- On-chip indexer supports up to 1/8 micro-stepping

- Programmable mixed (fast + slow) decay mode

- Integrated protection features including over-current, thermal, shoot-through and UVLO protection

- P2P replacement for competitors, and runs up to *30%* cooler.

特性

- 雙H 橋接步進電動驅動器
  - 供電電壓: 8~35V
  - 輸出電流: 每繞組 1.75A RMS / 2.5A 峰值

- DRV8811的接腳相容升級版，Rdson 更低 (0.37ΩHS+LS)

- 內建索引支援最高1/8細分

- 可程式的混合電流衰變（快速衰變+緩慢衰變）模式

- 包含過電流、過熱、擊穿與欠壓封鎖等整合保護特性

- 可接腳兼容代替其他公司的一些產品，同時運行溫度要低超過30%

Applications/應用範圍

- Printer/印表機
- Scanner/掃描機
- Textile Machinery/紡織機械
- Positioning & Tracking/定位 & 追蹤
- Factory Automation/工廠自動化
- Robotics/機器人技術

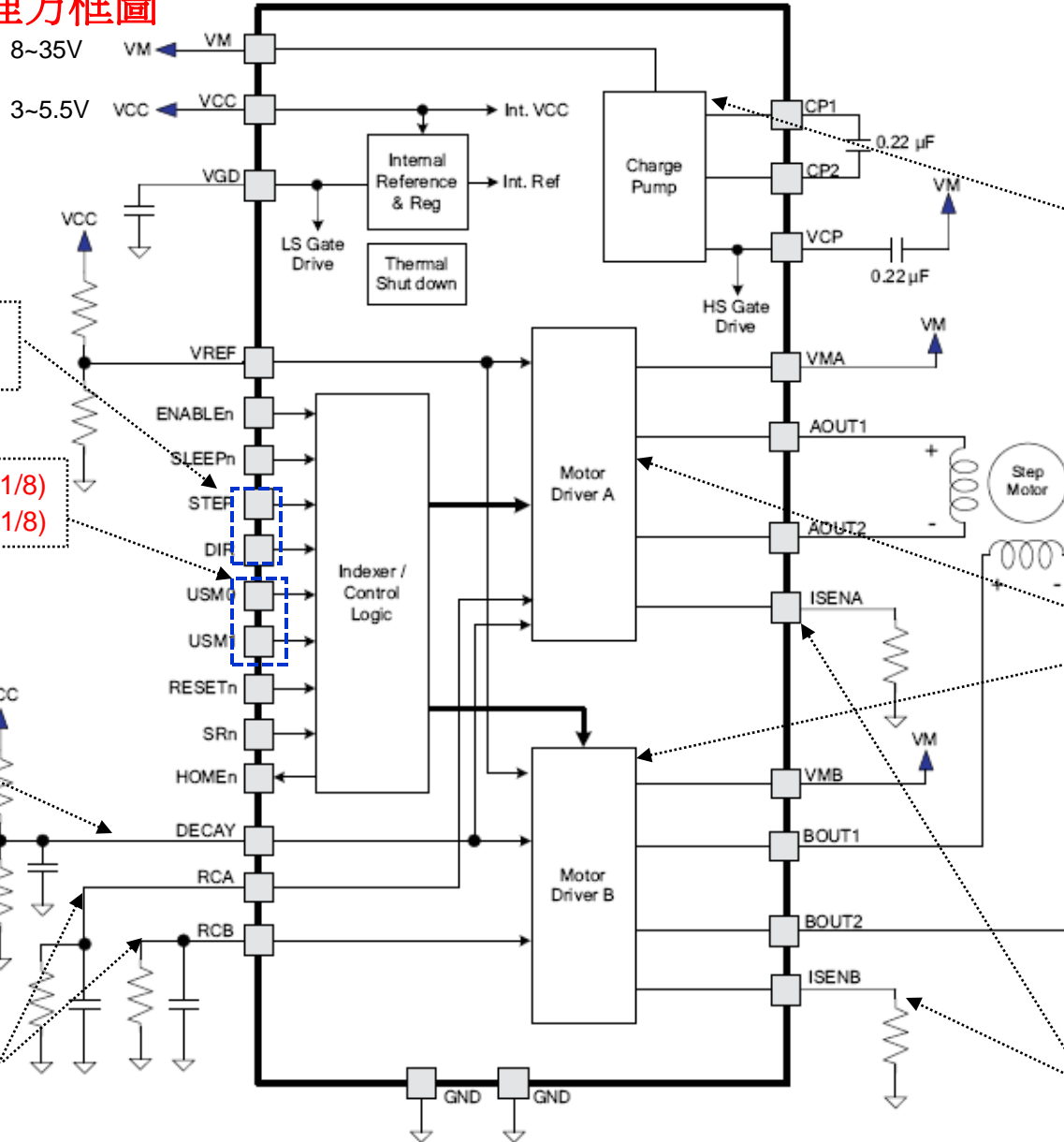9.7 x 6.4mm, 28-pin HTSSOP package

9.7 x 6.4mm, 28腳 HTSSOP封裝

Step / Direction

Controller

Step size

DRV8818 Motor Driver

3 to 5.5V

8 to 35V

1/8 u-steps

M
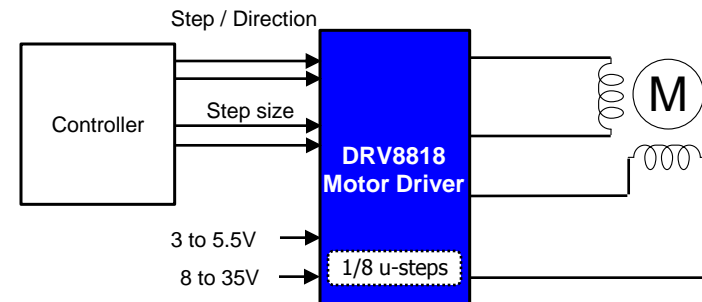
1/8 Micro-Stepping
1/8細分微步進驅動

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DRV8818 Functional Block Diagram
DRV8818 原理方框圖

Built-in charge pump
內置充電泵

Step/Direction control
步進/轉向控制

μ-stepping (full, 1/2, 1/4, 1/8)
微步進設置(full, 1/2, 1/4, 1/8)

Decay mode setting
電流衰減模式設定

PWM blanking and
off time setting
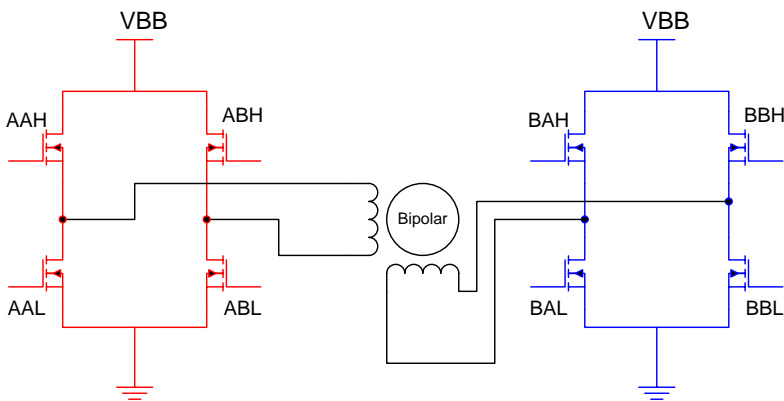PWM 消隱/關斷時間
設定

1.75A continuous
2.5A peak
1.75A 連續
2.5A 峰值

•NCH power MOSFETs
/N通道功率MOSFET
•Pre-driver/前置驅動器
•PWM/脈衝寬度調變
•Current Regulation/電流
調節

Current sense
電流感應

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μ-Stepping
微步進細分

- 1 bipolar stepper motor → 2 H-bridges, 2 phases.

- 2 Phases are alternated in a specific sequence to obtain the desired stepping rate and direction.

- Only when full current flows through the windings, the stepper is "full-stepped".

- 1個雙極步進馬達→2 個 H 橋接，雙相位

- 馬達的雙相交替開關生成一組驅動狀態，這組狀態的交替頻率與順序決定馬達的步進速度與方向.

- 當馬達持續在完全電流狀態下運轉時，該步進馬達被稱爲"全步運轉".

Bipolar Motor and Drive
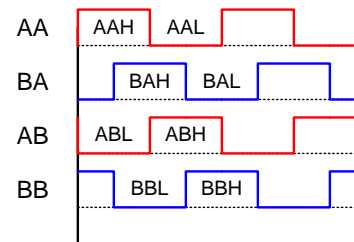
- Full step – 4 states/全步運行 –4個狀態

- Mechanical noise/機械雜訊

- Limited position resolution/有限的馬達位置解析度

- High power loss/功率損耗較大

TEXAS INSTRUMENTS

μ-Stepping
微步進細分

VBB

AAH ABH

BAH BBH

Bipolar

AAL ABL

BAL BBL

VBB

1 Step | 1 Step

8 MicroSteps | 8 MicroSteps
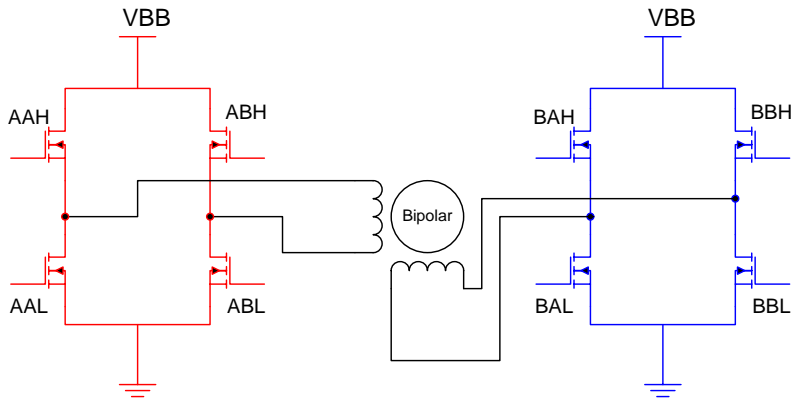
- By PWM chopping the current through windings is regulated to a multi-level waveform (e.g. sine), and a full step is divided into multiple smaller steps – μstepping.

- Less mechanical noise

- Higher position resolution

- Less power dissipation

- PWM 將線圈中的電流調製成爲一種波形（如正弦波），馬達的全步步進也被細分成爲很多更小的步進，是爲微步進細分。
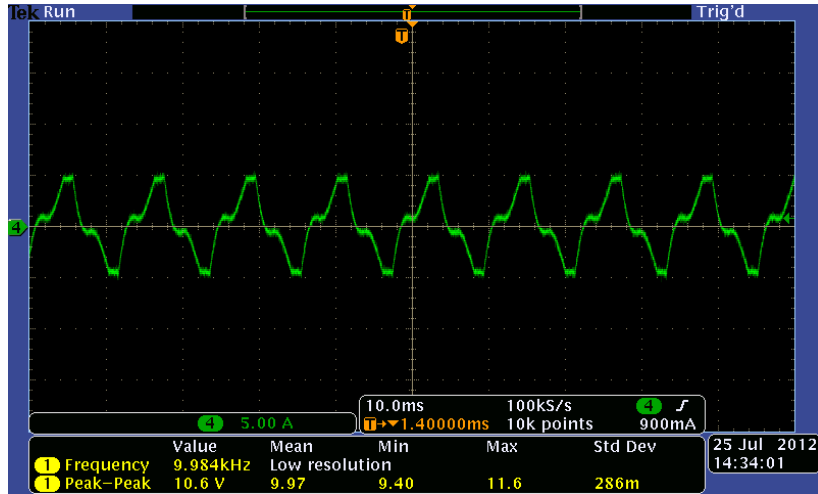
- 更小的機械雜訊

- 更高的位置解析度

- 更少的功率損耗

1 Step

AA

BA

Current AA

Current BA

TEXAS INSTRUMENTS
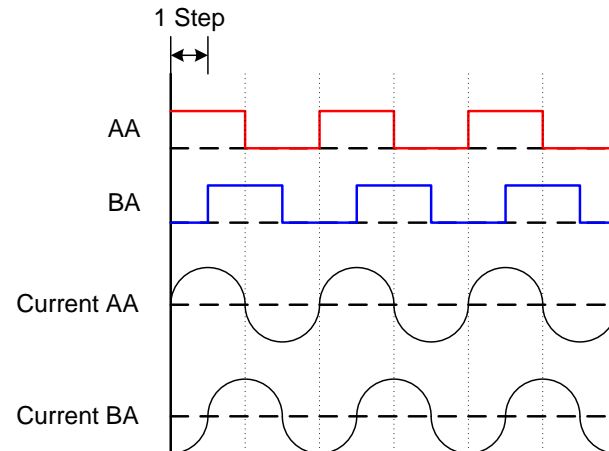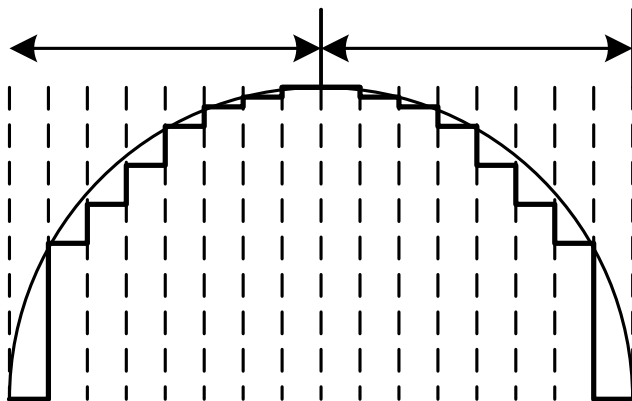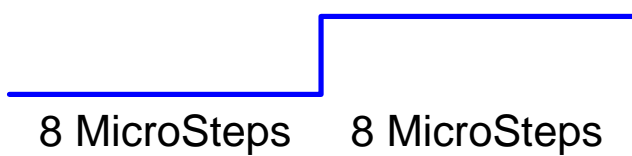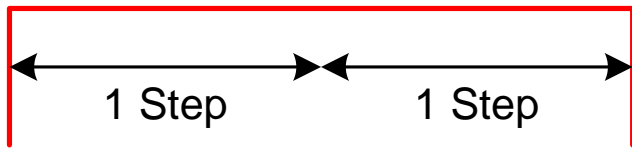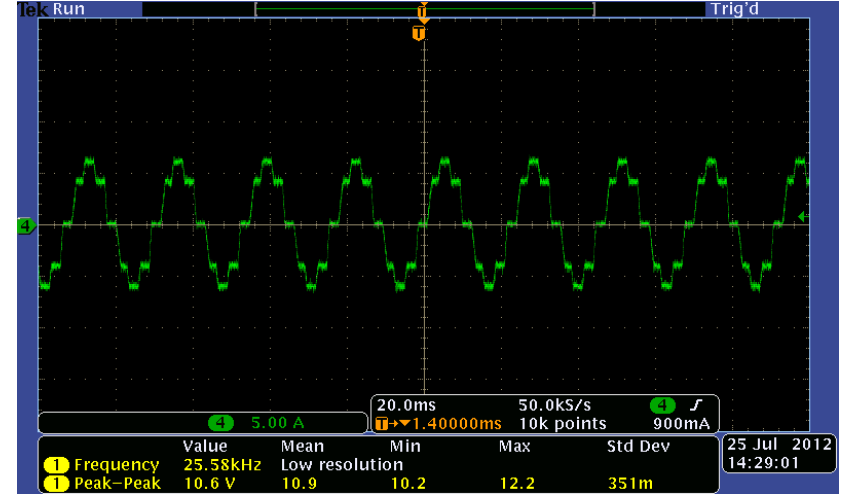
DRV8818 µStepping Current Waveform Example
DRV8818微步進細分電流波形範例

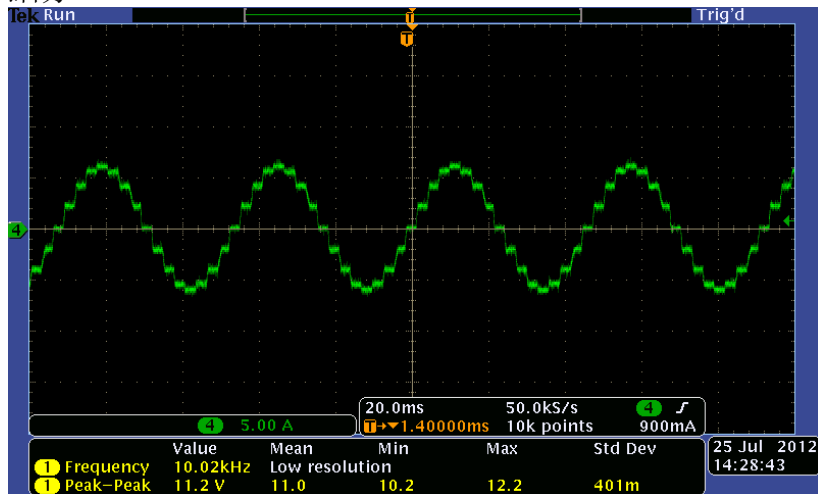Full stepping
全步步進

1/2 µ-stepping
1/2細分

1/4 µ-stepping
1/4細分

1/8 µ-stepping
1/8細分

Selective Disclosure
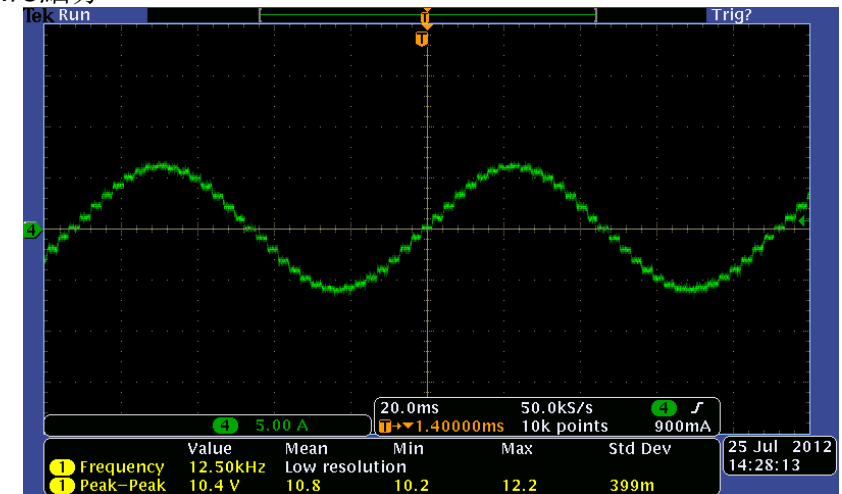
Another u-Stepping Form: Modulating VREF
另一種微步進細分的方式：調變 VREF

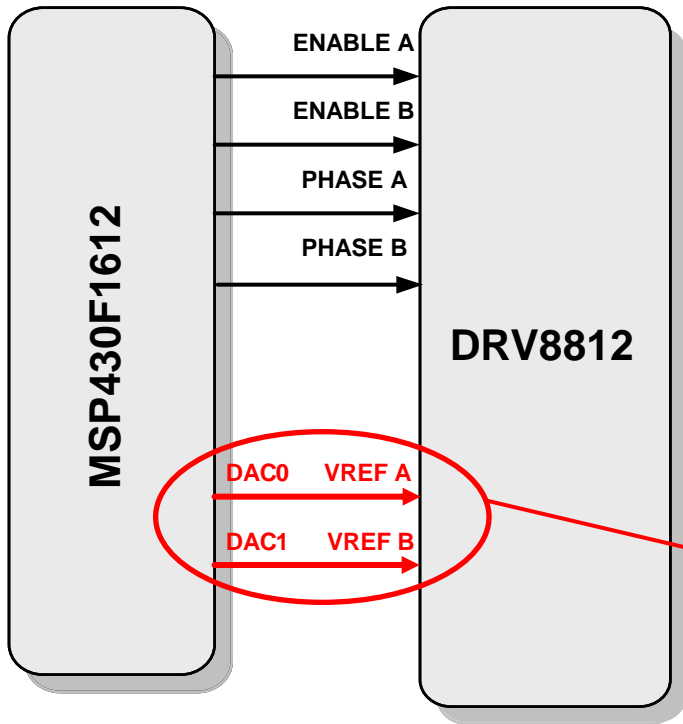1 Step

PHASE AB

PHASE CD

Vref AB

Vref CD

Current AB

Current CD

MSP430F1612

ENABLE A

ENABLE B

PHASE A

PHASE B

DRV8812

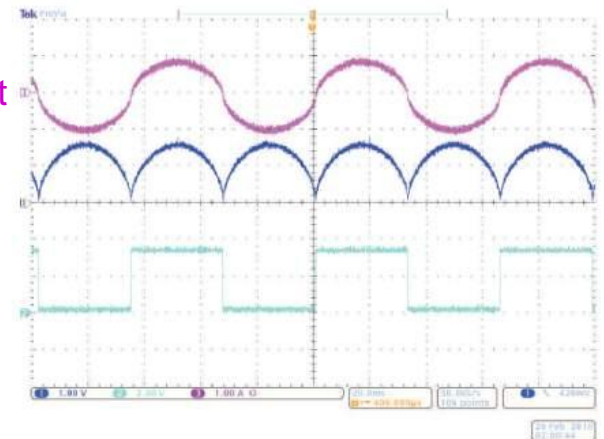DAC0   VREF A

DAC1   VREF B
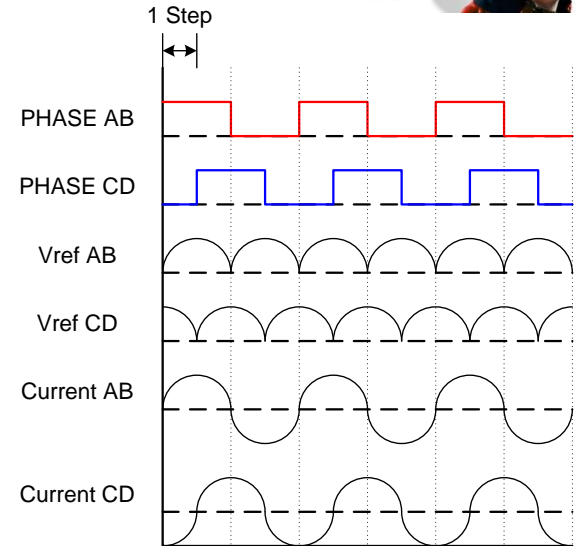
Winding Current

VREF

PHASE

Figure 7. Squared Sine Wave With 256 Degrees of Microstepping
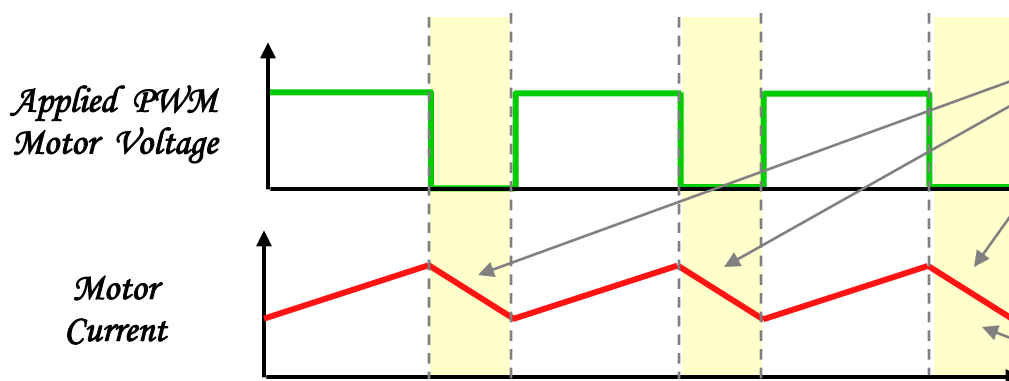
App Note: Download SLVA416 @www.ti.com today!!!

使用說明：立即透過 www.ti.com 下載 SLVA416！！！

TEXAS INSTRUMENTS

Inductive Recirculation Currents
電感再循環電流

Applied PWM Motor Voltage

Motor Current

Recirculation currents
再循環電流（續流）

$$\Delta I = (V/L)\ \Delta t$$

Torque ripple is the vibration of motor shaft. Noise=f(Torque ripple)

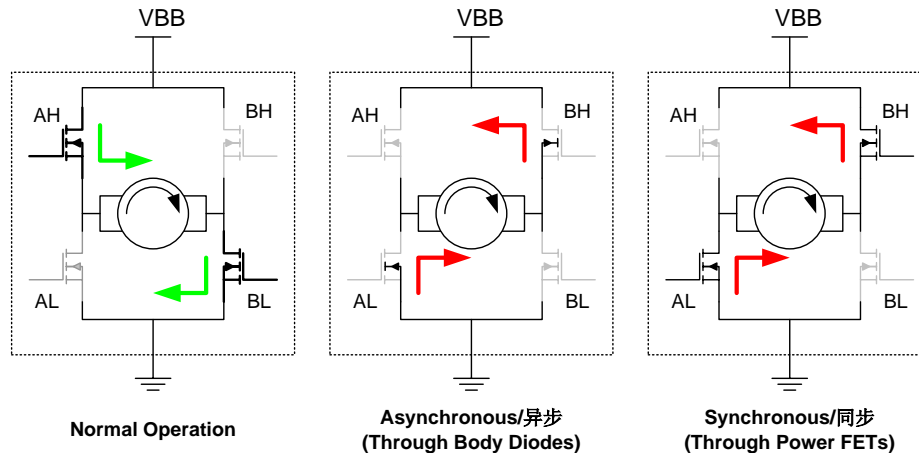Motor windings → inductors
馬達繞組→電感

While PWM=Low, current continues to flow (re-circulate) →current decay
當 PWM 為低時，電流會持續流動 (循環)→電流衰減

Slope/magnitude/frequency of the ripple affects torque ripple, noise, power…
漣波的斜率/幅度/頻率會影響到馬達的轉矩漣波、雜訊、功耗…

（轉矩漣波是馬達轉軸振動的結果，也是造成雜訊的原因）

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Current Recirculation: Fast Decay Mode
電流循環–快速衰減模式

Normal Operation

Asynchronous/异步
(Through Body Diodes)
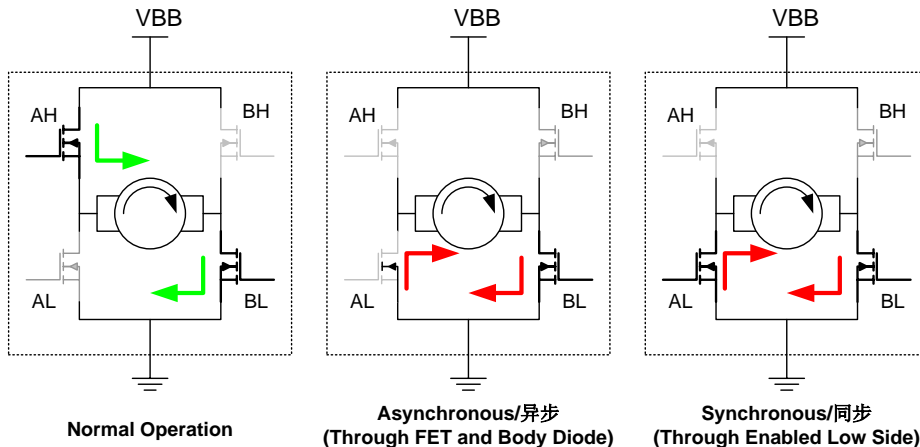
Synchronous/同步
(Through Power FETs)

"Fast" means current decays down towards 0 **FAST** when PWM is off. It doesn't mean that anything on inductive load (like motor speed) actuates fast.

"快速"意指 PWM 關斷時，電流向零電流方向衰減的速度快，並非指電感負載本身制動的快 (比如馬達轉速)。

- In fast decay mode, current flowing through the motor winding is working against the full supply voltage.

  在快速衰減模式下，馬達線組中的電流流向對抗滿載的電壓。

- Current decays quickly because of the opposite-polarity voltage applied to the winding.

  由於加載在繞組的電壓極性爲反向，電流衰減速度較快。

Selective Disclosure

Current Recirculation:Slow Decay Mode
電流循環–緩慢衰減模式

VBB

AH BH

AL BL

Normal Operation

VBB

AH BH

AL BL

Asynchronous/异步
(Through FET and Body Diode)

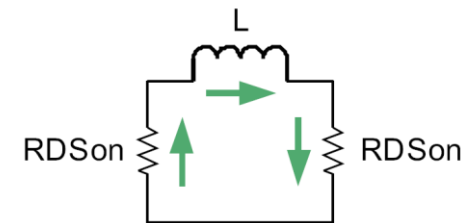VBB

AH BH

AL BL

Synchronous/同步
(Through Enabled Low Side)

"Slow" means current decays down towards 0 **SLOW** when PWM is off. It doesn't mean that anything on inductive load (like motor speed) actuates slow.
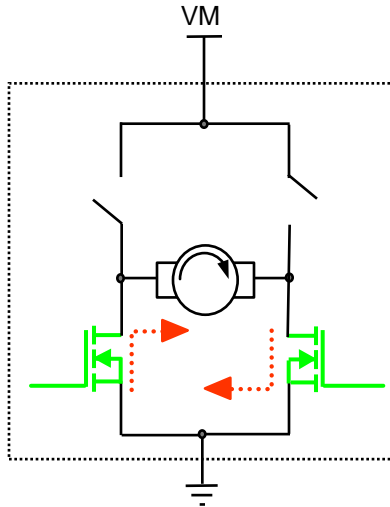
 "緩慢"意指 PWM 關斷時，電流向零電流方向衰減的速度慢，並非指電感負載本身制動的慢 (比如馬達轉速)。

Current is redirected through power MOSFETs presenting a resistive path to the current, leading to slower decay ($\propto$ L×2R).
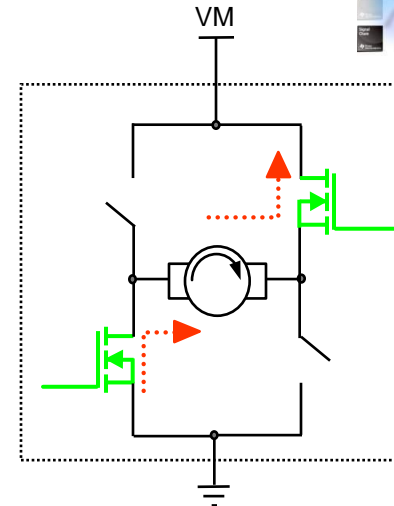
電流透過做爲電流抵抗路徑的功率 MOSFET 而改道，使電流衰減緩慢（ $\propto$ L×2R）。

L

RDSon   RDSon

TEXAS INSTRUMENTS

Slow Decay v.s. Fast Decay
緩慢衰減 v.s. 快速衰減

$$\Delta I = (V/L)\, \Delta t$$

Slow Decay/緩慢衰減

Fast Decay/快速衰減

Slow Decay/緩慢衰減

- Used when current is increasing as charging an inductor is always easy.

  緩慢衰減通常在繞組電流增加時使用，因爲爲電感充電總是容易的。

- Lower current ripple → less heating/smoother/quieter

  低電流漣波→ 散熱少、馬達運轉更順暢、噪音更小

- Increasing winding current when micro-stepping

  在進行微步進時，增加線圈電流

- Current may not decay fast enough for proper control in some applications (micro-stepping)

  在某些細分應用下，電流衰變可能不夠快，難以實現理想的控制

Fast Decay/快速衰減

- Used when current is decreasing as discharging an inductor is difficult.

  快速衰減通常在繞組電流減小時使用，因爲爲電感放電比較困難。

- Higher current ripple → more heating/ more torque ripple/louder

  較大的電流漣波→ 散熱多，馬達轉矩漣波大、雜訊較大

- But can provide better motion profile when winding current is decreasing during micro-stepping

  但在步進馬達微步進驅動的應用中，當馬達線圈繞組中電流減小時，電流衰減速度快，更容易實現理想的驅動狀態

TEXAS INSTRUMENTS

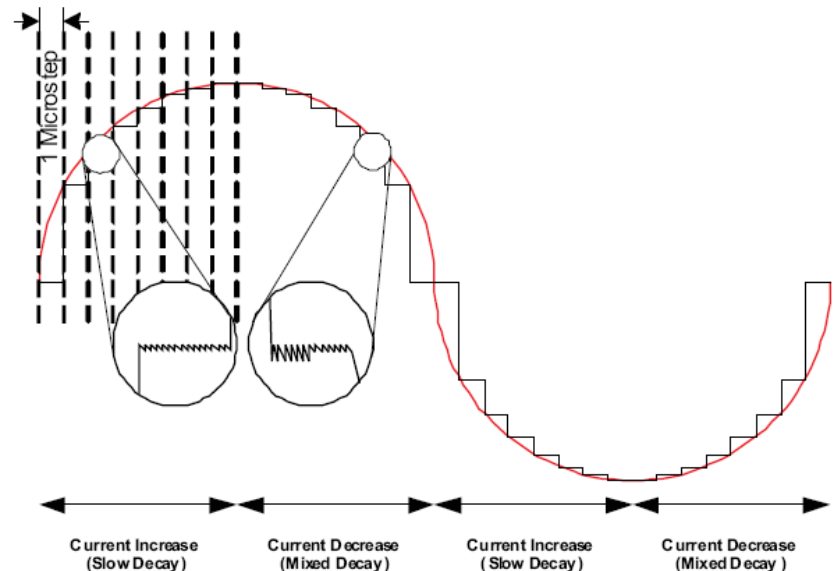# Mixed Decay: Fast + Slow, Best of Both!!
混合衰減模式：合二爲一，各取所長！！

- As motor speed gets faster, it is more difficult to follow μ-stepping waveform because of motor inductance – ***mixed decay*** can accommodate the wave shape!

  馬達轉速越快，由於馬達電感的阻礙，就越難準確重現細分所定義的波形。這時*混合模式*就發揮作用了！

  – Current ↑ → slow decay (less EMI & improved efficiency during recirculation)

  電流↑→緩慢衰減（EMI小，效率高）

  – Current ↓ → mixed decay (a balance between fast decay and slow decay)

  電流↓→混合衰減 （在二者中尋求一個平衡）

- Coordinate FET switching-ON and -OFF time so that fast decay is engaged for a fixed amount of time, and subsequently engage slow decay for the remaining period of time.

  透過調節功率管打開/關斷的時間，使馬達在快速衰減模式下工作一個固定的時間，而在剩下的時間採用緩慢衰減模式。
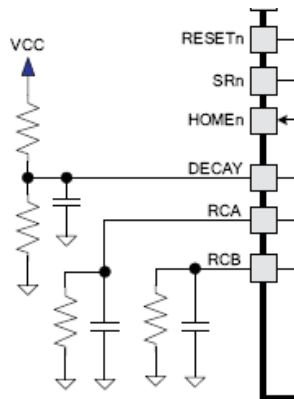
DRV8818 allows the user to set Fast Decay/Slow Decay ratio by tuning voltage on DECAY pin.
DRV8818允許用戶通過設定DECAY管脚的電壓來調節混合衰減模式中二者的比例。

VCC RESETn SRn HOMEn DECAY RCA RCB

1 Microstep

Current Increase (Slow Decay) | Current Decrease (Mixed Decay) | Current Increase (Slow Decay) | Current Decrease (Mixed Decay)

TEXAS INSTRUMENTS

Different Decay Modes Current Waveform Example
不同衰減模式下的電流波形示例

Fast decay
快速衰減

Slow decay
緩慢衰減

Lower current with higher ripple
平均電流更小，漣波更大

Higher current with lower ripple
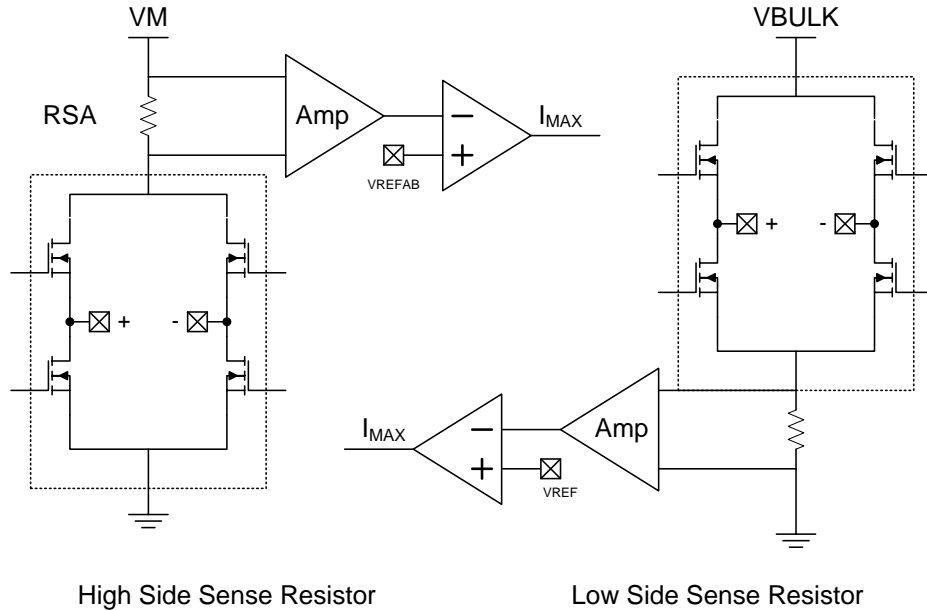平均電流更大，漣波更小

Mixed decay
混合衰減

Fast Decay   Slow Decay
快速衰減   緩慢衰減

Somewhere in between
中間的平衡點

TEXAS INSTRUMENTS

Current Regulation
電流調節

$$I_{CHOP} = \left(\frac{V_{REF}}{GAIN \bullet R_{SENSE}} \right)$$

VM

RSA

Amp

I_{MAX}

VREFAB

VBULK

I_{MAX}

Amp

VREF

High Side Sense Resistor

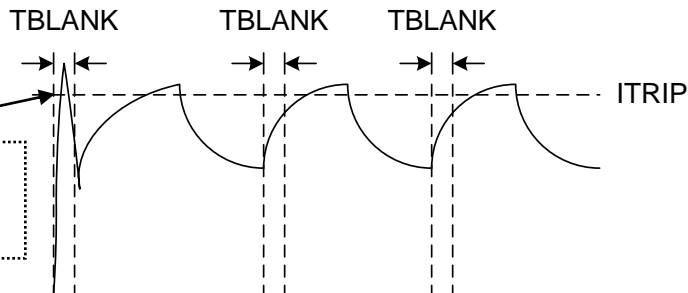Low Side Sense Resistor

TBLANK   TBLANK   TBLANK

ITRIP

False Itrip
avoided/避免Itrip
誤判

- When a winding is activated by PWM chopping, the current through it rises until it reaches chopping current threshold "Ichop".

  線圈在PWM訊號的作用下會產生電流，此電流會持續增長直到達到電流閾值。

- Then all the FETs are OFF for a discretely adjustable fixed time.

  之後所有功率管都會在一個固定時間內持續關斷（此一固定時間可透過離散元件進行調節）。

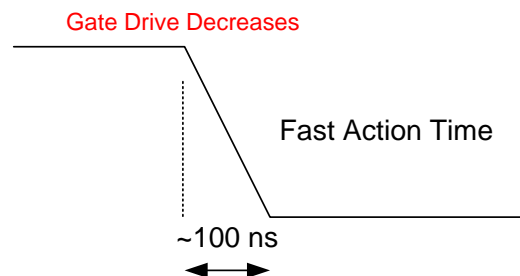- A blanking period should be employed immediately after turning on the FETs to ignore current sense operation, in order to avoid false-tripping on transients.

  在打開功率管後應馬上利用一段消隱時間來忽略電流檢測電路的作用，避免因暫態電流而導致的功率管關斷誤判。

Over Current Protection
過電流保護

Without OCP: Current rises to destructive levels

With OCP: Current is limited, then driver turns off

I_{OCP}

T_{OCP}

Gate Drive Decreases

Fast Action Time

~100 ns

Gate Drive

Time
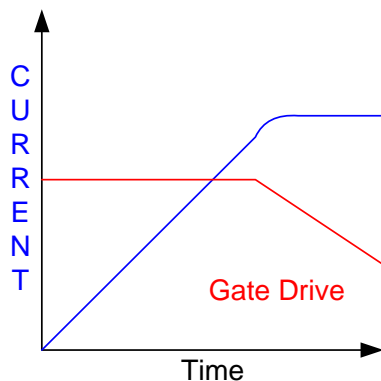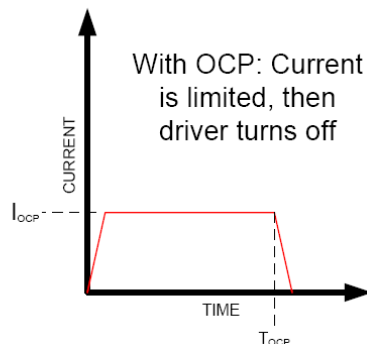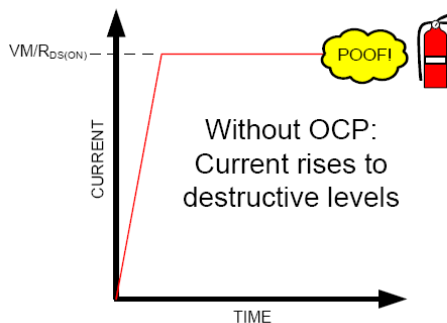
- Need to protect from damage caused by motor fault condition, e.g. short to GND, supply or across motor winding.

  與地、電源或線圈之間的短路等情況都需要過流保護。

- On Top of current regulation circuit, TI devices contain an extra protection called I_{LIMIT}.

  不同於電流調節電路，TI的產品一般都包括另外一個保護電路 "I_{LIMIT}"。

- By decreasing FET gate drive, the FET DS resistance increases and current is limited.

  透過減小功率管的門極電壓，其源漏極電阻會增加，限制通過的電流。

- Each FET is protected individually and need to react fast enough without false-triggering.

 每個功率管都需要單獨的保護機制，同時需要能迅速對過流情況進行反應，又不能有誤判。

UVLO/Shoot-through Protection
欠壓閉鎖/擊穿保護

- UVLO protection/欠壓閉鎖
  - Supply voltage level is constantly monitored and the device is tri-stated when the voltage level is too low to ensure proper control over the H-Bridge

    晶片自行持續監測供電電壓值，當電壓過低時輸出端被設置成高阻抗狀態，確保H橋接在正常運作狀態。

- Shoot-through Protection/擊穿保護
  - High side and low side onthe same half bridgeare never allowed to turn on at the same time. A small amount of delay (dead time) is insertedbetween high-side turning-off and low-side turning-on. The longer the dead time, the safer the operation but the worse the linearity and efficiency.

    同一個半橋的上低側決不允許同時打開！爲了避免此現象的發生，高側關斷和低側導通之間人爲的增加一段延時 (停滯時間/死區)。停滯時間越長H橋接的運作越安全，但同時線性度和效率也越差。

VBB

AH

BH

AL

BL
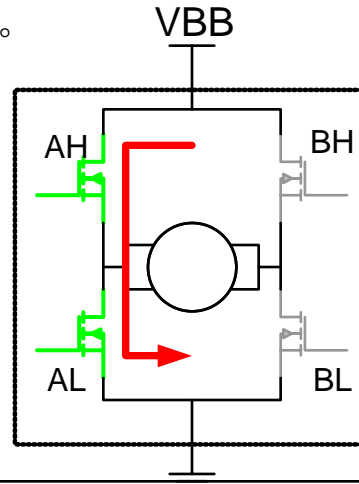
Shoot–through!!

Thermal Shutdown
熱關斷

- Excessive power dissipation, insufficient heat-sinking or a too high ambient temperature can lead to hazardous temp level.
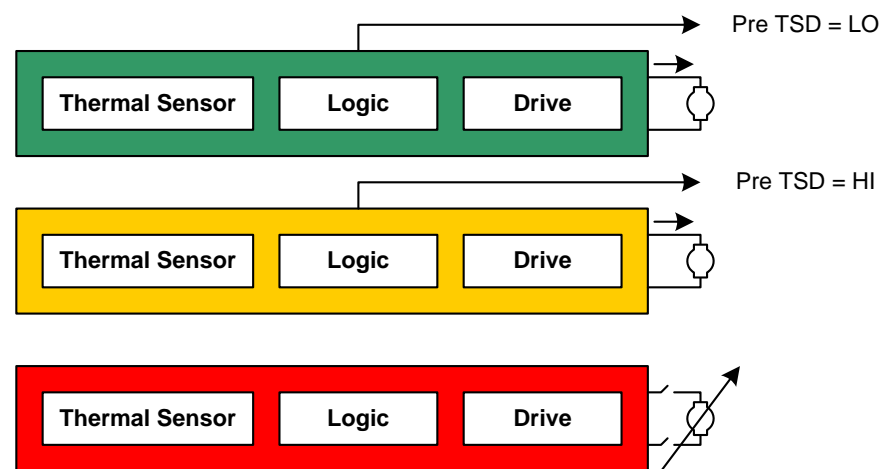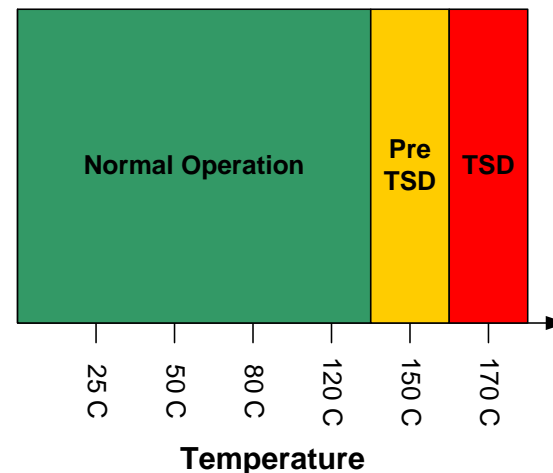
  過度發熱、熱沉不足、環境溫度過高等都可能對晶片造成損害。

- Multiple thermal sensors are placed across the die, continuously monitoring temperature. When temperature reaches over-temp threshold, the H-bridge is tri-stated and indexer is reset, and a Thermal ShutDown (TSD) event occurs.

  晶片內部放置了多個熱感應器來持續監控溫度。當芯片溫度上升到過熱的閾值時，H橋接將被設置成高阻，微步進細分也被重置–熱關斷。

- Some devices offer a warning signal called Pre-TSD. A Pre-TSD event occurs at the TSD-XC temperature, where XC is a temperature offset such as 20°C or 30°C.
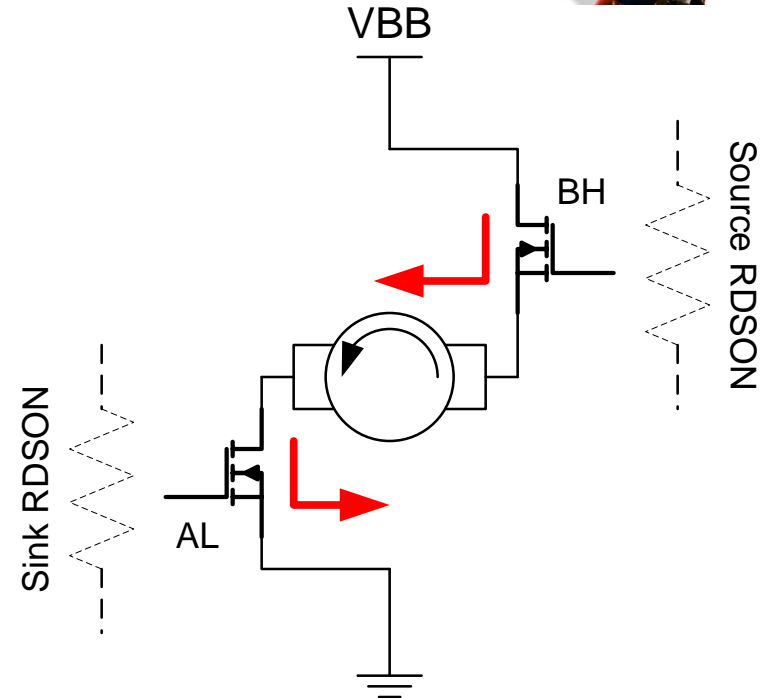
  有些產品在熱關斷之前可以先進行預判，預判溫度一般比熱關斷閾值低20～30°C。

Normal Operation	Pre TSD	TSD

25 C 50 C 80 C 120 C 150 C 170 C

Temperature

Pre TSD = LO

Thermal Sensor	Logic	Drive

Pre TSD = HI

Thermal Sensor	Logic	Drive

Thermal Sensor	Logic	Drive

TEXAS INSTRUMENTS

Thermal Performance: RDSon & Package
散熱性能： **RDSon**與封裝

- RDSON increases over temperature
  隨著溫度的升高RDSON會增加
- RDSON is often less on the Sink (Low Side) driver, as the current recirculation often takes place through this switch
  低側的RDSON通常會更小，因爲電流再環流（電流衰減）一般通過低側來完成

Device RDS On	Driver	RDSON @ 25C°
DRV8818 Typical RDS On	Sink (Low Side)	0.15
DRV8818 Typical RDS On	Source (High Side)	0.22
DRV8818 Max RDS On	Sink (Low Side)	0.24
DRV8818 Max RDS On	Source (High Side)	0.30

VBB

BH

Source RDSON

Sink RDSON

AL

The PowerPAD™ package uses an exposed pad to remove heat from the device.
PowerPAD™封裝透過使用裸焊盤來進行散熱。

TEXAS INSTRUMENTS

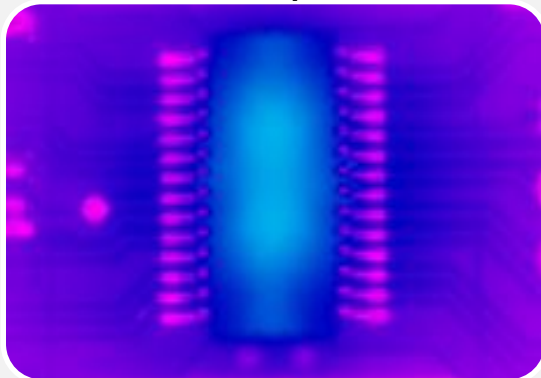# DRV8818 – The Coolest 2.5A µStepping Motor Driver
DRV8818 – 溫度最低的細分步進馬達驅動器

Greater than 30% temperature reduction

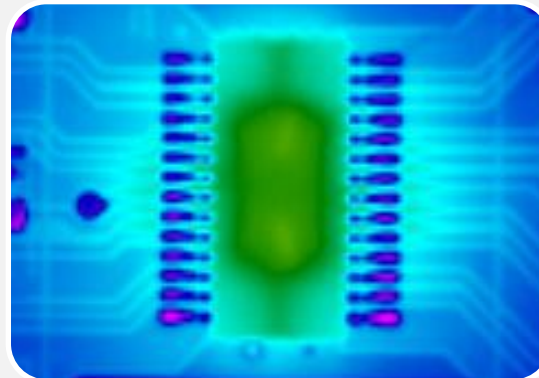*Pin to pin compatible drops into existing layout!*
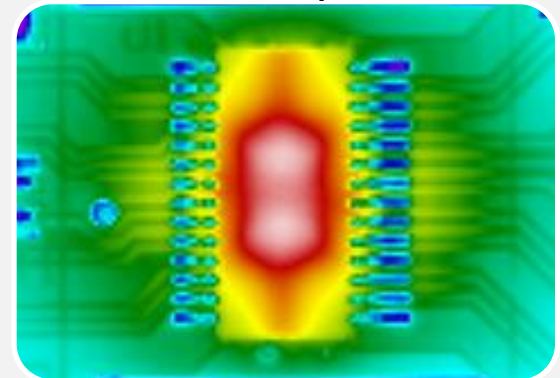
相比其他互相接腳兼容的產品，DRV8818溫度要低過30%！

Max Temp 107°C	Max Temp 130°C	Max Temp 157°C
TI - DRV8818	Competitor 1	Competitor 2

2.5A sine wave peak, 1/8 micro-stepping, 2-layer board

TEXAS INSTRUMENTS

DRV8837:1.8A Low Voltage Brushed DC Motor Driver
DRV8837：1.8A低電壓直流有刷馬達驅動器

Features

- Single H-Bridge motor driver
  - Dual supplies: Vm = 1.8 to 11V
    - Vcc = 1.8 to 7.0V
  - Output current: 1.8A cont / 1.8A peak
  - RDSON: 280mΩ (LS + HS)
- PWM control interface (IN/IN)
- Brake support
- Sleep mode operation (35nA @ 5V)
- Tiny 2 x 2mm package
- Extended battery life
- On-chip fully protected

特性

- 單H橋接驅動器
  - 馬達/邏輯雙電源:Vm = 1.8~11V
    - Vcc = 1.8~7.0V
  - 輸出電流:1.8A cont / 1.8A peak
  - RDSON:280mΩ (LS + HS)
- PWM型控制接口 (IN/IN)
- 支馬達制動
- 支持休眠模式 (35nA @ 5V)
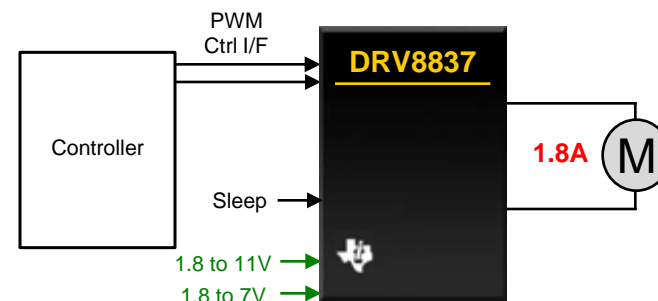- 2 x 2mm封裝
- 延長電池使用壽命
- 全面整合保護機制

Applications/應用範圍

- Battery-powered consumer products/電池供電類消費電子
- Low voltage solenoids& relays/低壓螺線管&繼電器
- Portable medical devices/可攜式醫療設備
- Toys/玩具
- E-locks/電子鎖

2.0 x 2mm, 8-pin WSON package

2.0 x 2mm, 8接腳 WSON封裝

PWM Ctrl I/F
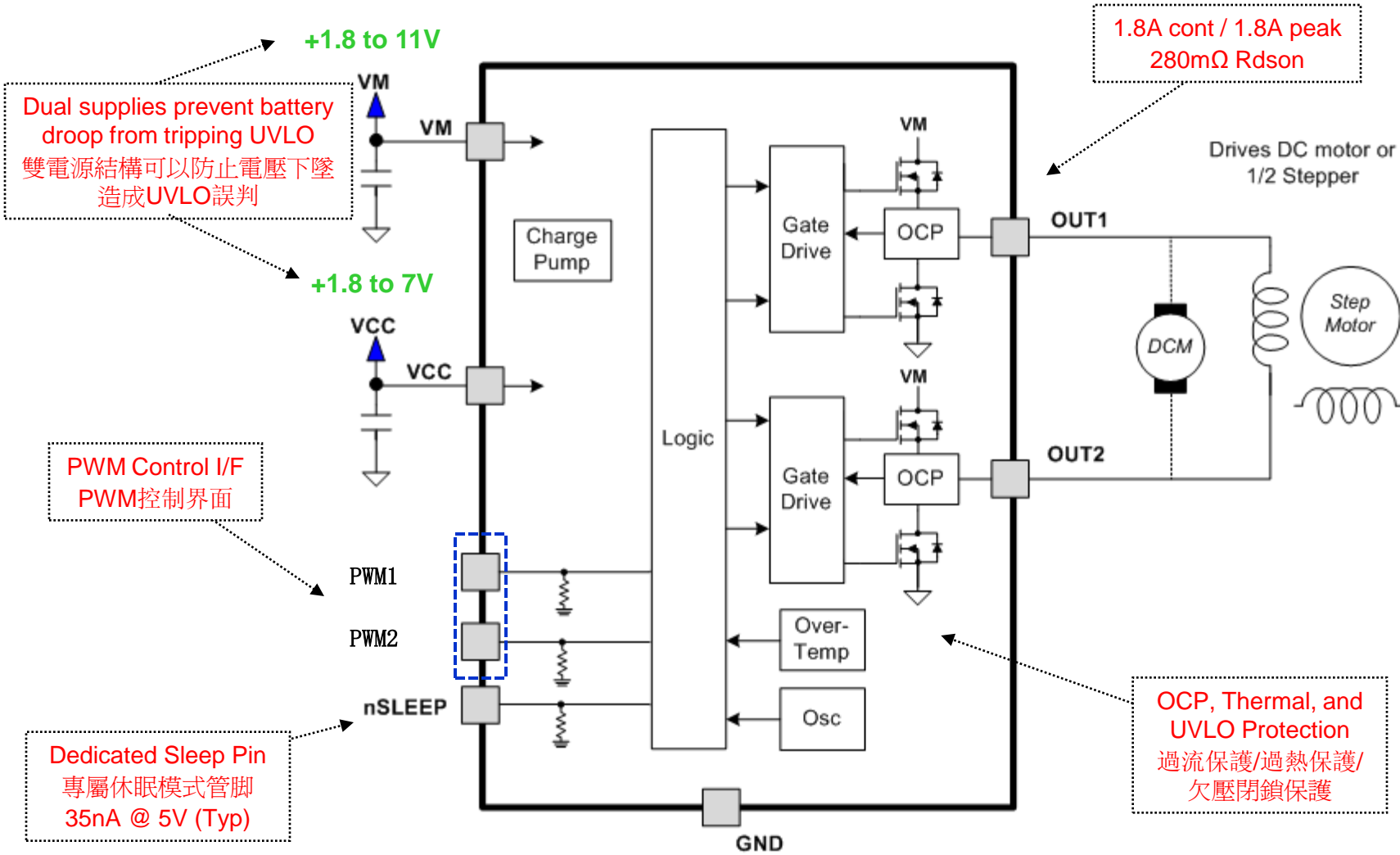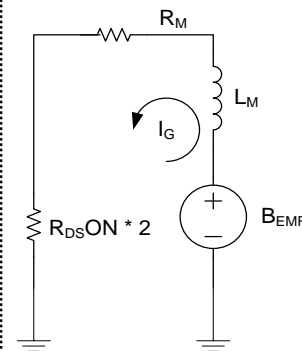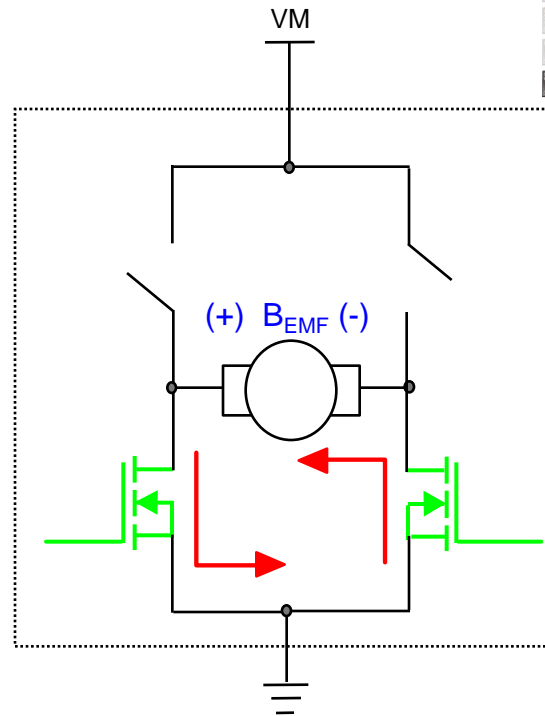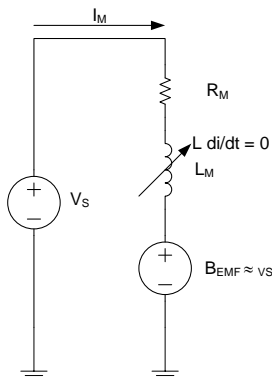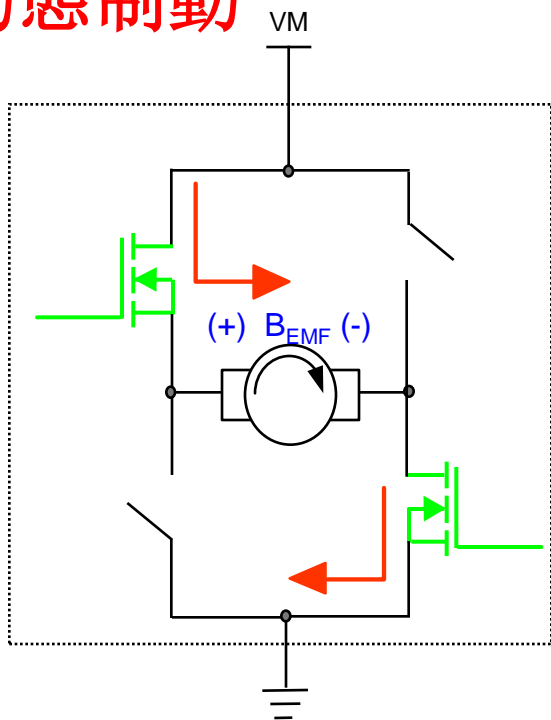
DRV8837

Controller

1.8A M

Sleep

1.8 to 11V
1.8 to 7V

TEXAS INSTRUMENTS

DRV8837 Functional Block Diagram
DRV8837原理框圖

+1.8 to 11V

1.8A cont / 1.8A peak 280mΩ Rdson

Dual supplies prevent battery droop from tripping UVLO
雙電源結構可以防止電壓下墜造成UVLO誤判

+1.8 to 7V

PWM Control I/F
PWM控制界面

Dedicated Sleep Pin
專屬休眠模式管腳
35nA @ 5V (Typ)

OCP, Thermal, and UVLO Protection
過流保護/過熱保護/欠壓閉鎖保護

Dynamic Braking
動態制動

VM

VM

(+) B$_{EMF}$ (-)

I$_M$

R$_M$

L di/dt = 0
L$_M$

V$_S$

B$_{EMF}$ ≈ VS

(+) B$_{EMF}$ (-)

R$_M$

L$_M$

I$_G$

R$_{DS}$ON * 2

B$_{EMF}$

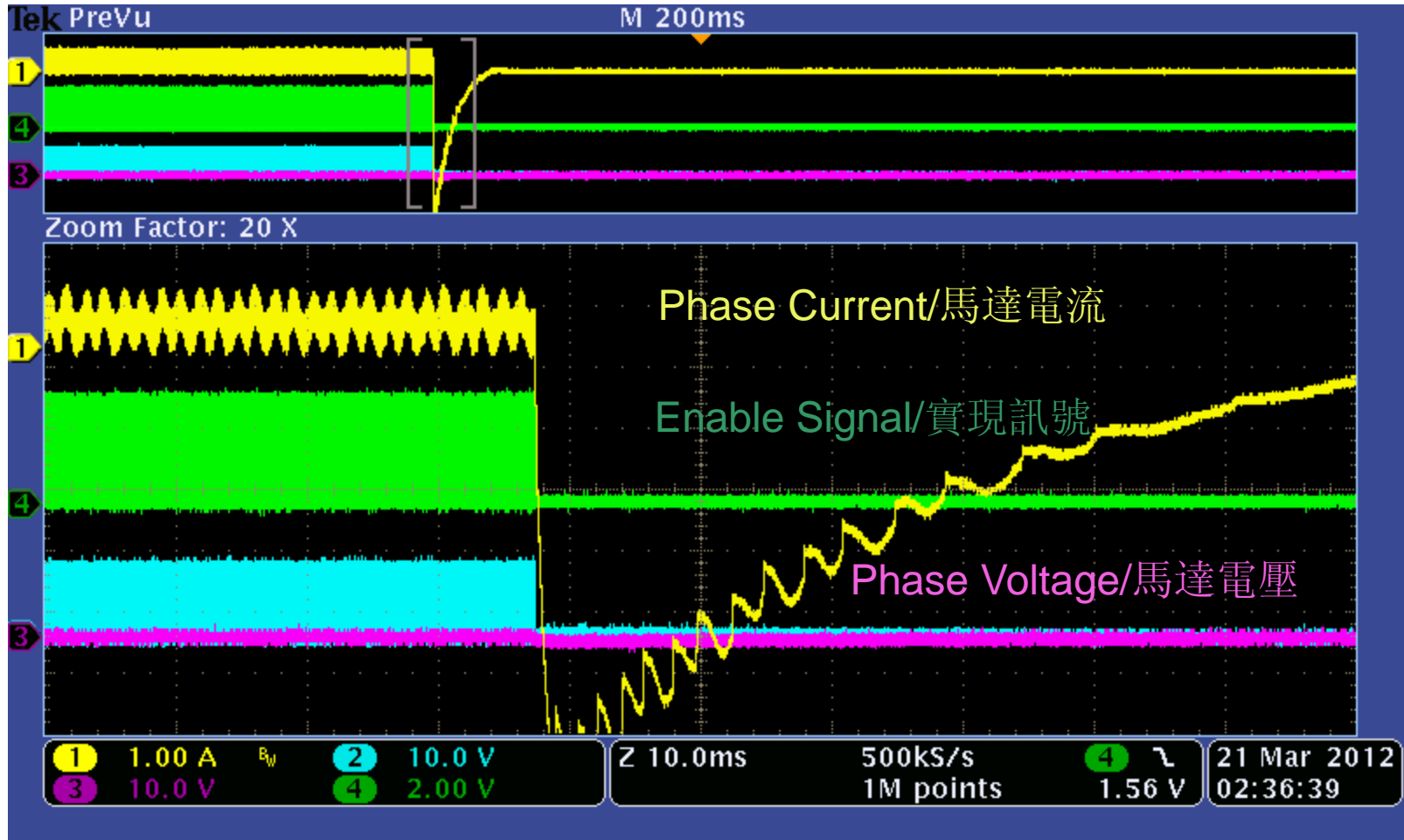**Normal Operation/**正常工作狀態
VM >Vmotor >BEMF

Braking/制動狀態
BEMF Stops Motor/反電動勢制動馬達

- By shorting the motor leads, you allow BEMF to drive current in opposite direction than normal operation mode, quickly braking the motor to stop.
  透過短路馬達的兩端，反電動勢將馬達電流帶向與正常工作狀態時相反的電流方向，使馬達快速制動。
- The energy stored in the motor is dissipated by "resistive load".
  儲存在馬達上的能量被 "阻抗負載" 快速消耗掉。

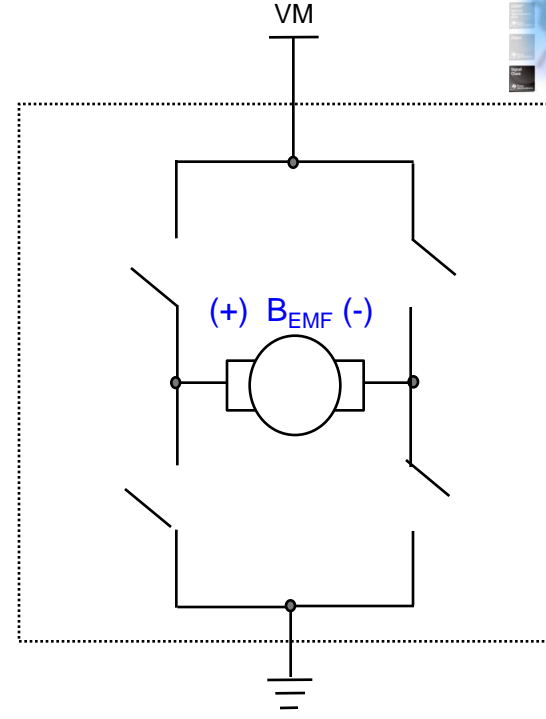**TEXAS INSTRUMENTS**

DC Motor Brake Waveform
直流馬達制動波形

Coasting/滑動
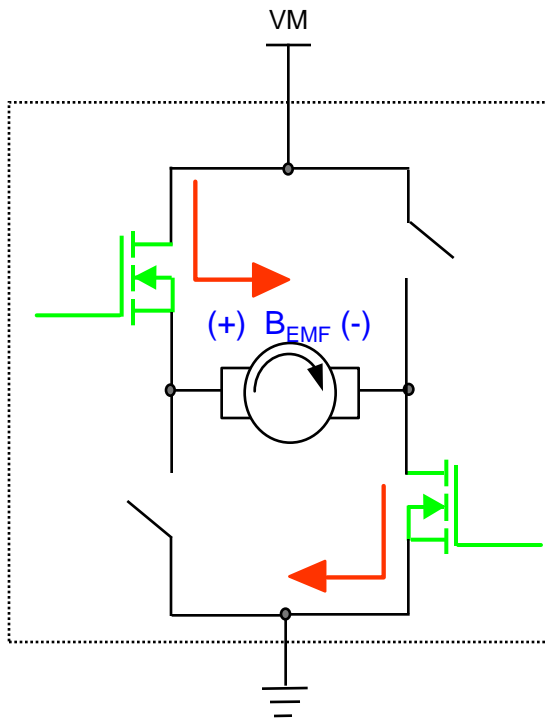
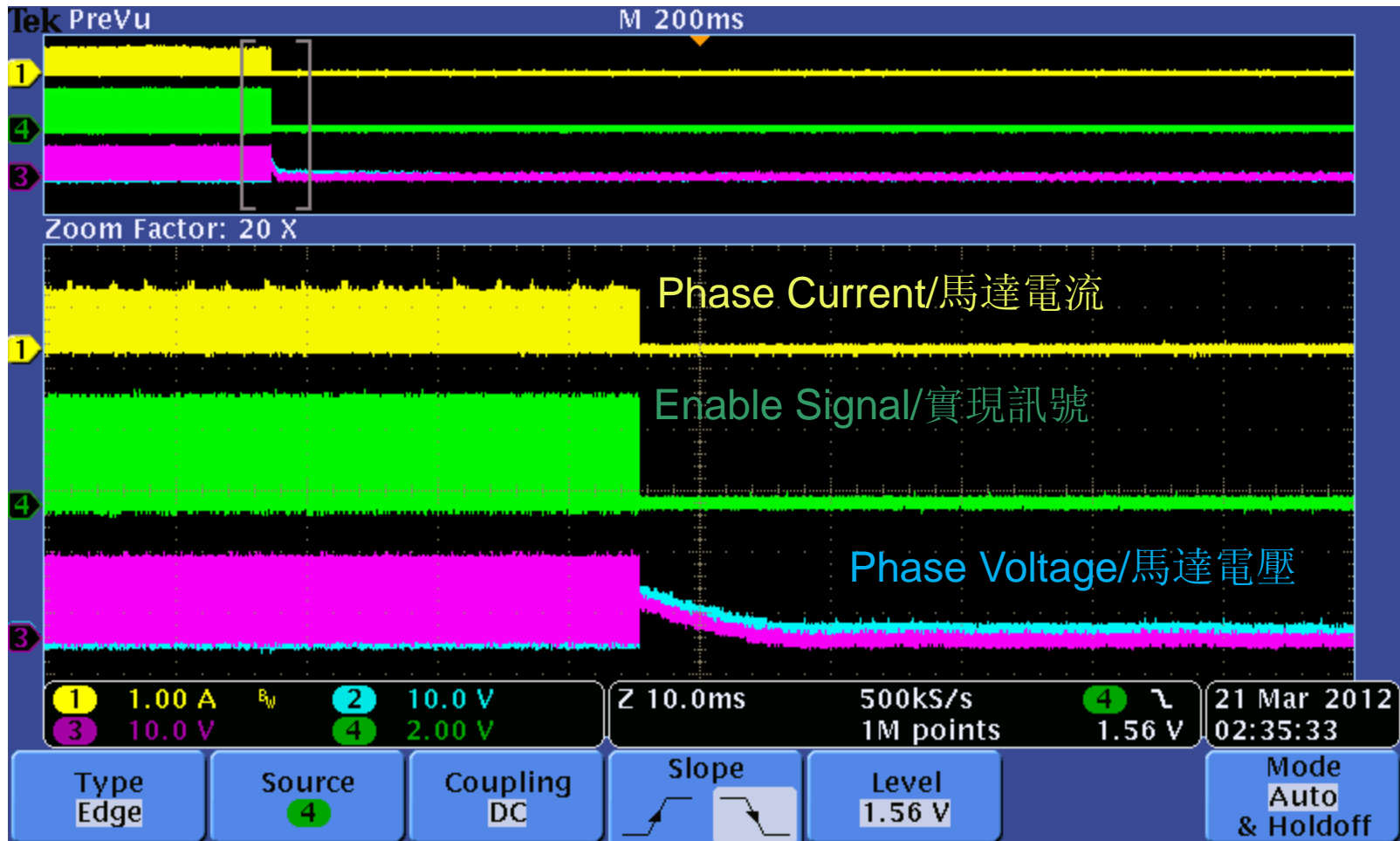**Normal Operation/正常工作狀態**
VM >Vmotor >BEMF

Coasting/滑動

- Since all the switches of the H-bridge are switched off, there is no current path, and the motion will die down slowly.
  由於 H 橋接的開關全部關斷，橋中無法形成電流回路，馬達會緩慢滑動直到停止。
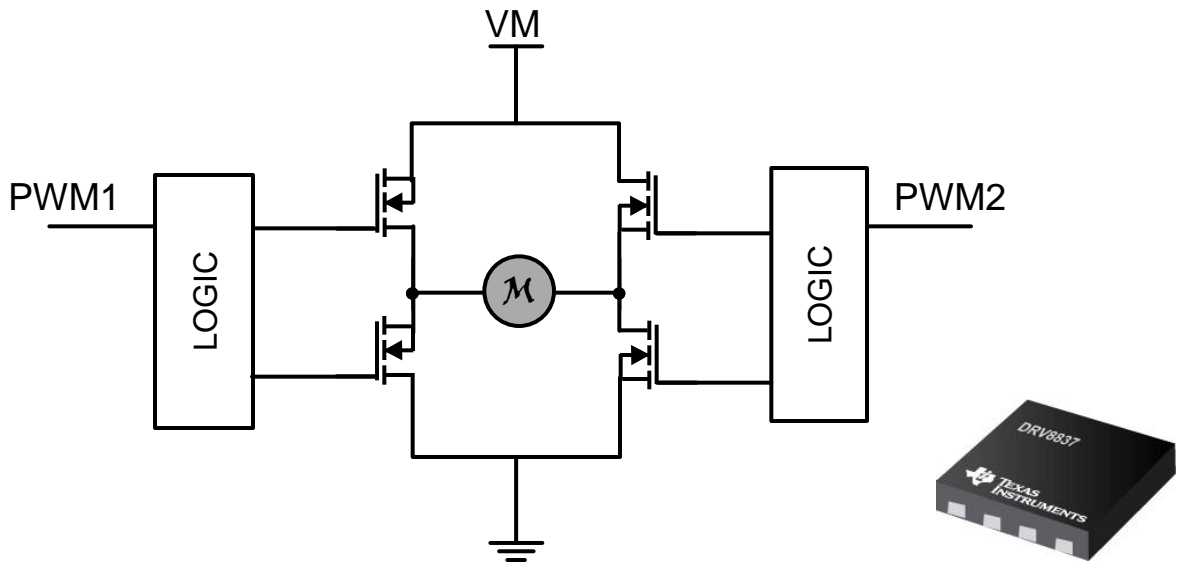- The energy stored in the motor is dissipated by friction.
  儲存在馬達上的能量被摩擦消耗掉。

DC Motor Coast Waveform
直流馬達滑動波形

DRV8x Brushed DC Driver Interface Style: PWM Interface
DRV8x有刷直流馬達驅動接口類型：PWM型

VM

PWM1 ─── LOGIC ─── [H-Bridge with Motor M] ─── LOGIC ─── PWM2

DRV8837

PWM I/F Example #1
H-Bridge Logic

| PWM1	PWM2	OUT1	OUT2
0	0	Z	Z
0	1	L	H
1	0	H	L
1	1	H	H

- Each half bridge can be controlled independently– can drive two different inductive loads.
  每個半橋可以獨立控制一個感性負載。
- Control logic can vary depending on application.
  控制邏輯可根據具體應用進行相應調整。
- Require 2 control signals to control speed/direction for a DC motor.
  對于一個直流馬達需要使用兩個信號去控制轉速和方向。

PWM I/F Example #2
H-Bridge Logic

PWM1	PWM2	OUT1	OUT2
0	0	L	L
0	1	L	H
1	0	H	L
1	1	H	H

TEXAS INSTRUMENTS

DRV8x Brushed DC Driver Interface Style: PHASE/ENABLE Interface
DRV8x有刷直流馬達驅動接口類型：PHASE/ENABLE型

VM

B_High

H ENABLE

A_High

LOGIC

H PHASE

A_Low

B_Low
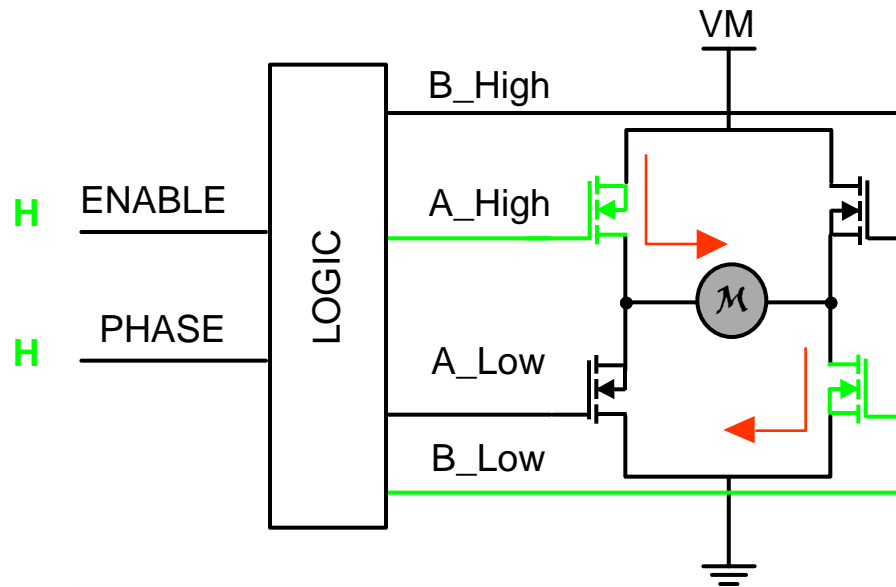
ENABLE	PHASE	½ Bridge A	½ Bridge B
L	L	HIZ	HIZ
L	H	HIZ	HIZ
H	L	GND	VM
H	**H**	**VM**	**GND**

- Internal logic automatically controls all 4 FETs.
  內部邏輯電路自動控制全部4個功率場效電晶體 (FET)。
- *ENABLE* signal turns on or off the entire H-bridge.
  ENABLE 訊號實現開/關整個H橋接功能.
- *PHASE* signal selects conducting direction of the H-bridge.
  PHASE 決定H橋接導通方向。
- A single PWM signal can control speed and/or direction.
  單一PWM訊號即可控制馬達速度和/或轉向
- Only one inductive load can be driven.
  只驅動一個電感負載。

TEXAS INSTRUMENTS

PWM in Motor Drive
馬達驅動的脈衝寬度調變

20 KHz   Max Freq

Audible

Switching Losses

Run Smoothness

Switching PWM Frequency
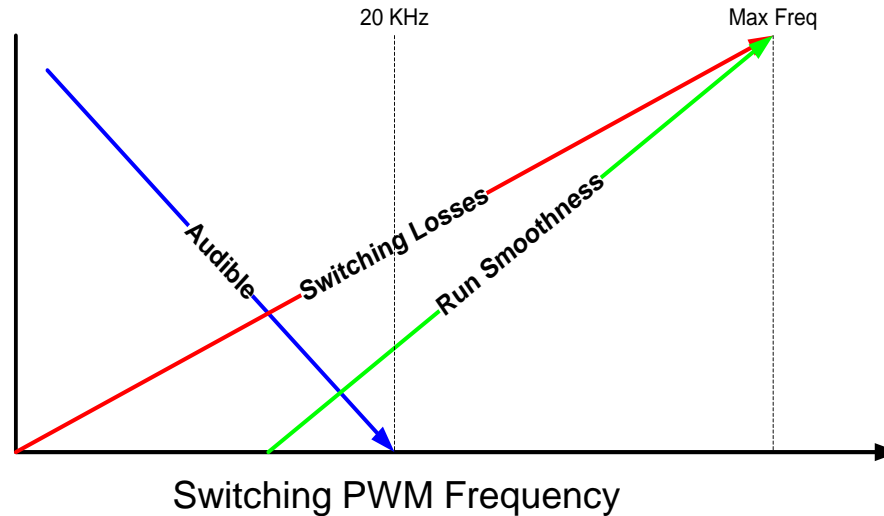
- The higher the PWM frequency, the less torque ripple and smoother the motion profile
  脈衝寬度調變 (PWM) 頻率越高，力矩漣波越小，馬達運轉越順

- Ideally, PWM frequency should be above 20 KHz to avoid audible noise.
  理想情況下脈衝寬度調變 (PWM) 頻率應高過20KHz以避免噪音。

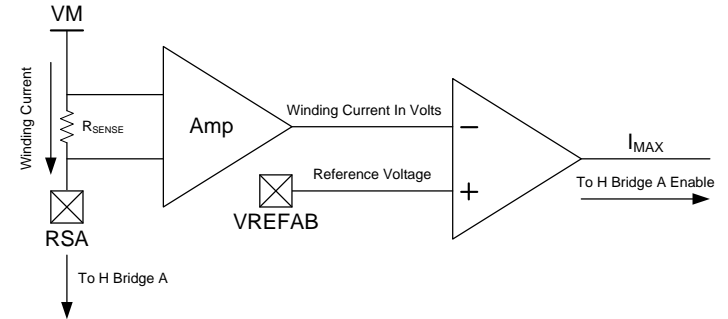- The higher the frequency, the higher the switching losses at the H-Bridge.
  頻率越高在H橋接上的損耗也越大。

TEXAS INSTRUMENTS

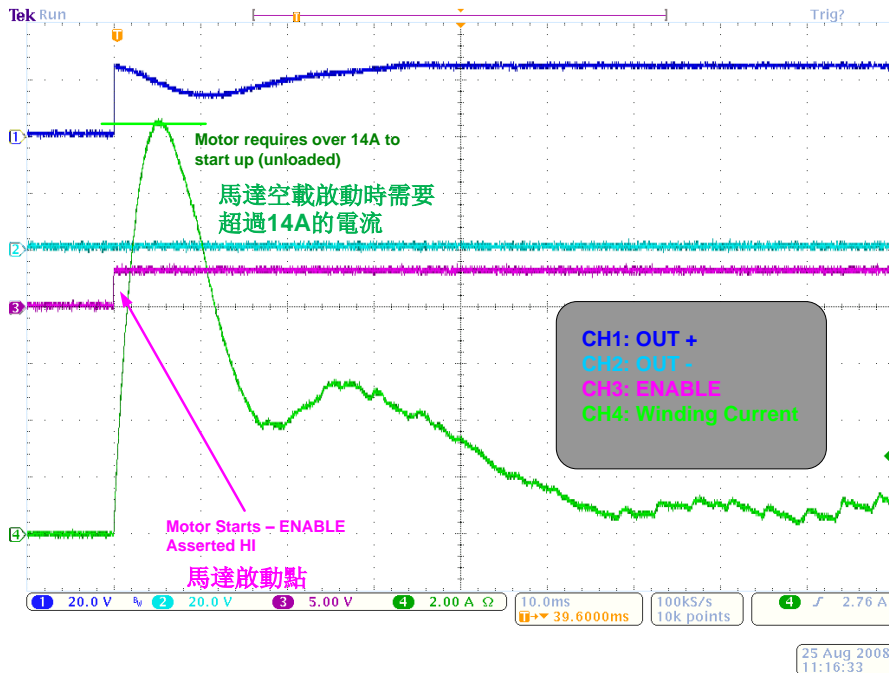# Current Regulation in Brushed DC Motor Drive
有刷直流馬達驅動中的電流調節

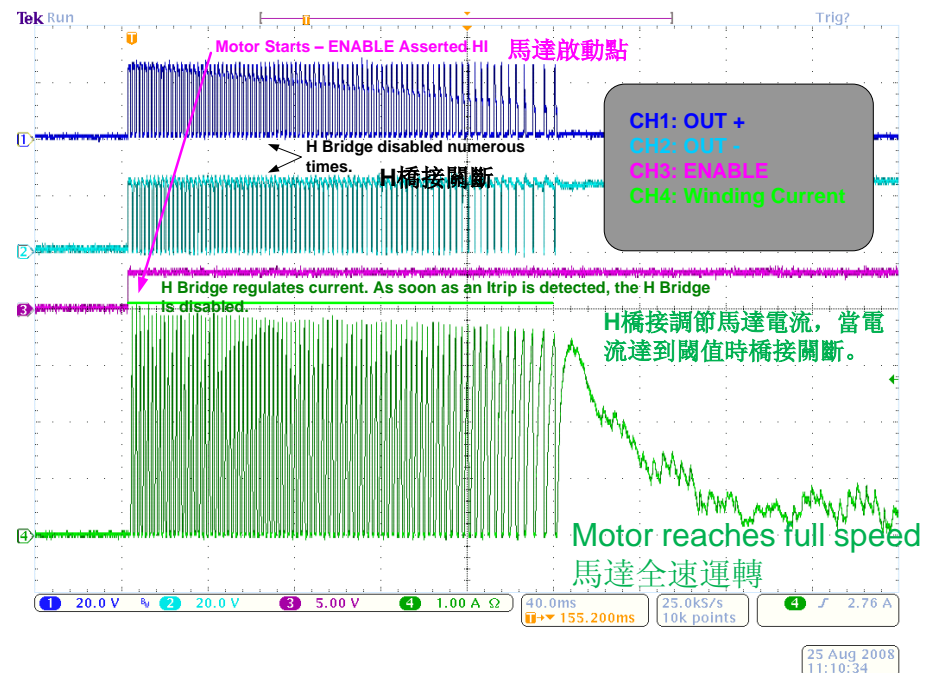We need current regulation to limit stall/inrush currents in Brushed DC motor drive.

在驅動有刷直流馬達時，需要以電流調節來限制停止/堵轉電流 (stall current) 和突波電流 (inrush current)。

Motor startup without current control/無電流調節的啟動

Motor requires over 14A to start up (unloaded)

馬達空載啟動時需要超過14A的電流

CH1: OUT +
CH2: OUT -
CH3: ENABLE
CH4: Winding Current

Motor Starts – ENABLE Asserted HI
馬達啟動點

Motor startup with current control/有電流調節的啟動

Motor Starts – ENABLE Asserted HI 馬達啟動點

H Bridge disabled numerous times.
H橋接關斷

CH1: OUT +
CH2: OUT -
CH3: ENABLE
CH4: Winding Current

H Bridge regulates current. As soon as an Itrip is detected, the H Bridge is disabled.

H橋接調節馬達電流，當電流達到閾值時橋接關斷。
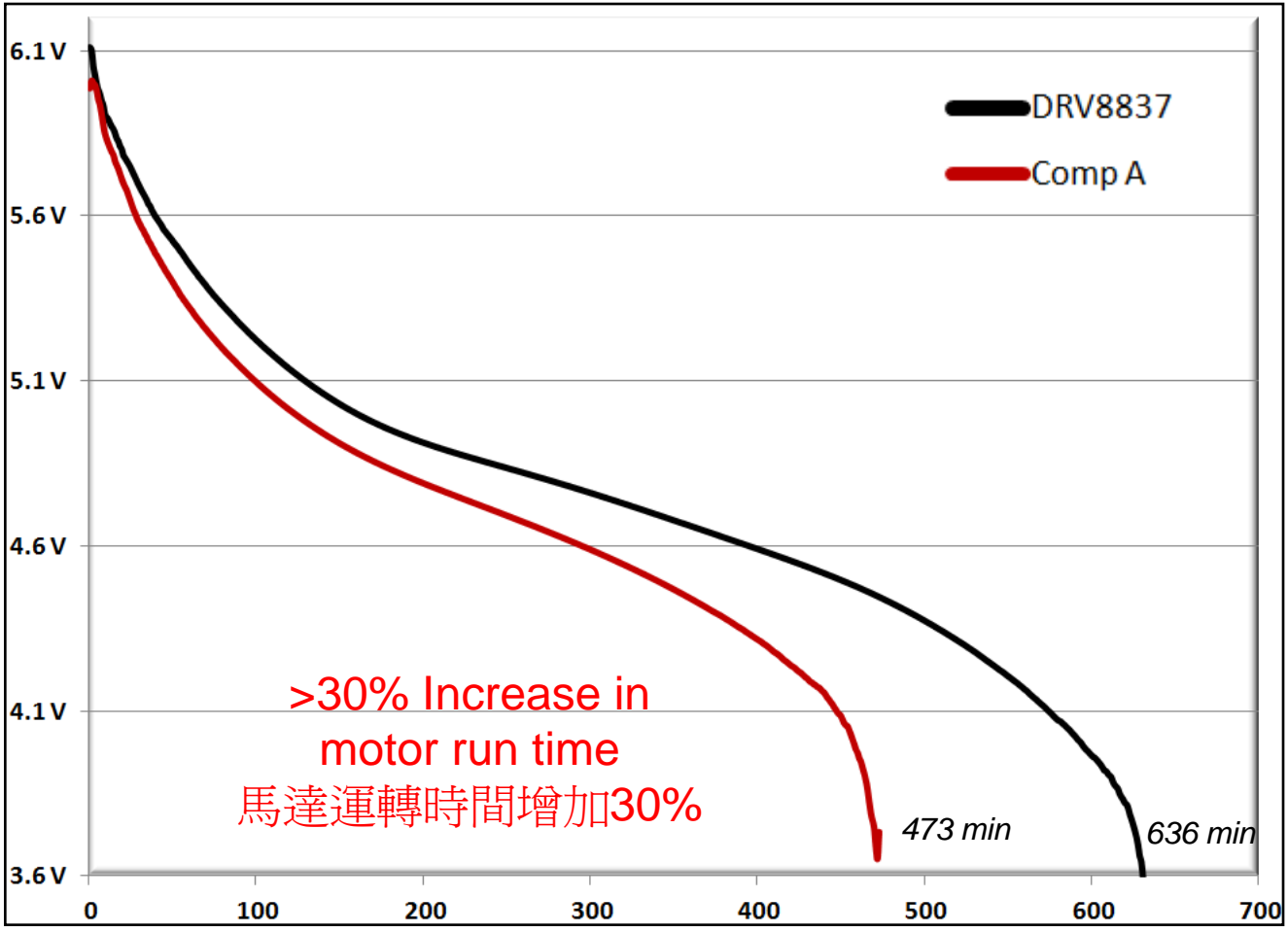
Motor reaches full speed
馬達全速運轉

TEXAS INSTRUMENTS

**DRV8837Extends Battery Life:*over 2.5 Hours longer run time!*
DRV8837延長電池壽命超過 *2.5小時！***

4x AA batteries (6V), motorvoltage set @4.7V (PWMed),250mA (@ start). Batteries "dead" at 3.6V
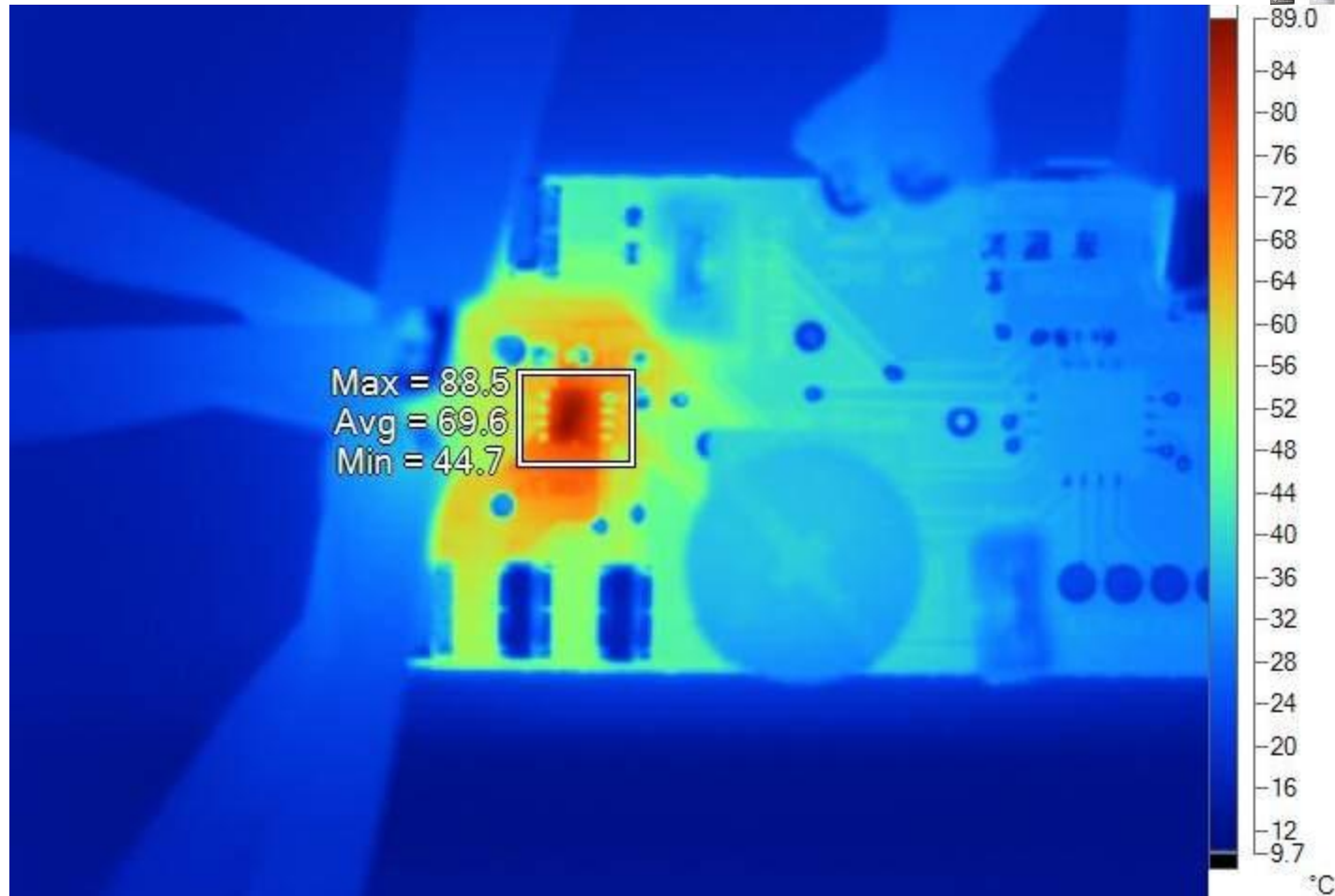4節5號電池（6V），馬達電壓經PWM被設置在 4.7V、250mA（啟動時）。電池在3.6V失效。

>30% Increase in motor run time
馬達運轉時間增加30%

473 min   636 min

DRV8837
Comp A

Battery Voltage/電池電壓

Motor OperationTime (Min)/馬達運轉時間（分鐘）

DRV8837: Excellent Thermal Performance:
DRV8837: 超好的散熱效能

Max *case temp = 88.5℃ @ 1.8A*

TEXAS INSTRUMENTS

DRV8837 – World's Smallest 1.8A Brushed DC Motor Driver
DRV8837 – 業界最小1.8A 直流有刷馬達驅動器

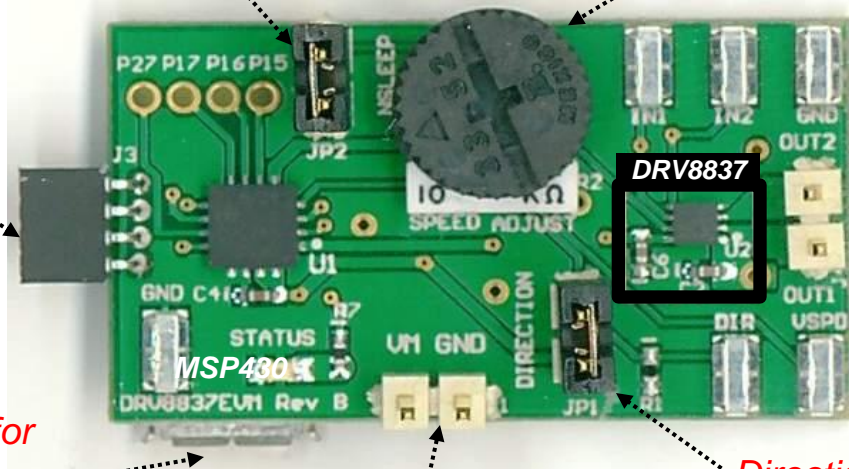*Sleep Mode Jumper/休眠模式跳線*

Speed Control/速度控制

eZ430-F2013 Programming Port/ 編程接口

Connect to Motor/ 連接馬達處

Micro-USB Connection for Easy Power Up/ Micro-USB接口可直接供電

Motor Supply/馬達供電 (If Not Using Micro USB)

Direction Jumper/轉動方向跳線 (jumper)

Selective Disclosure

DRV8844 – 2.5A Quad Half-Bridge Driver with Split Supply Rail Support
DRV8844 – 2.5A四通道分立地線半橋驅動器

Features

- Quad ½ Bridge driver
  - Supply voltage: 8.2 to 60V
  - Current per ½ bridge: 1.75A RMS / 2.5A peak
  - Low RDSON: 200mΩ per FET

- Outputs can be paralleled for higher current and / or better thermal performance

- PWM control interface with independent enables

- "Split-Rail" isolates MCU GND and driver GND

- On-chip 3.3V LDO (10mA)

- On-chip fully protected

特性

- 四通道半橋驅動器
  - 電壓範圍: 8.2~60V
  - 半橋電流: 1.75A RMS / 2.5A peak
  - RDSON: 200mΩ per FET

- 可通過並聯輸出端得到更好的電流驅動能力和/或散熱性能

- 獨立ENABLE的PWM型接口

- 數位控制器的地線與IC地線相互隔離
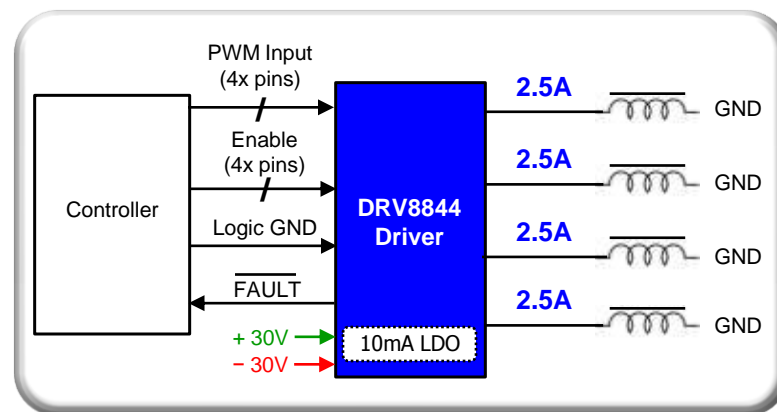
- 整合3.3V LDO (10mA)

- 整合保護機制

Applications/應用範圍

- Textile machines/紡織機械
- Factory automation/工廠自動化
- Office automation machines/商用機器
- Gaming machines/賭博機
- Robotics/機器人技術

9.7 x 6.4mm, 28-pin HTSSOP package
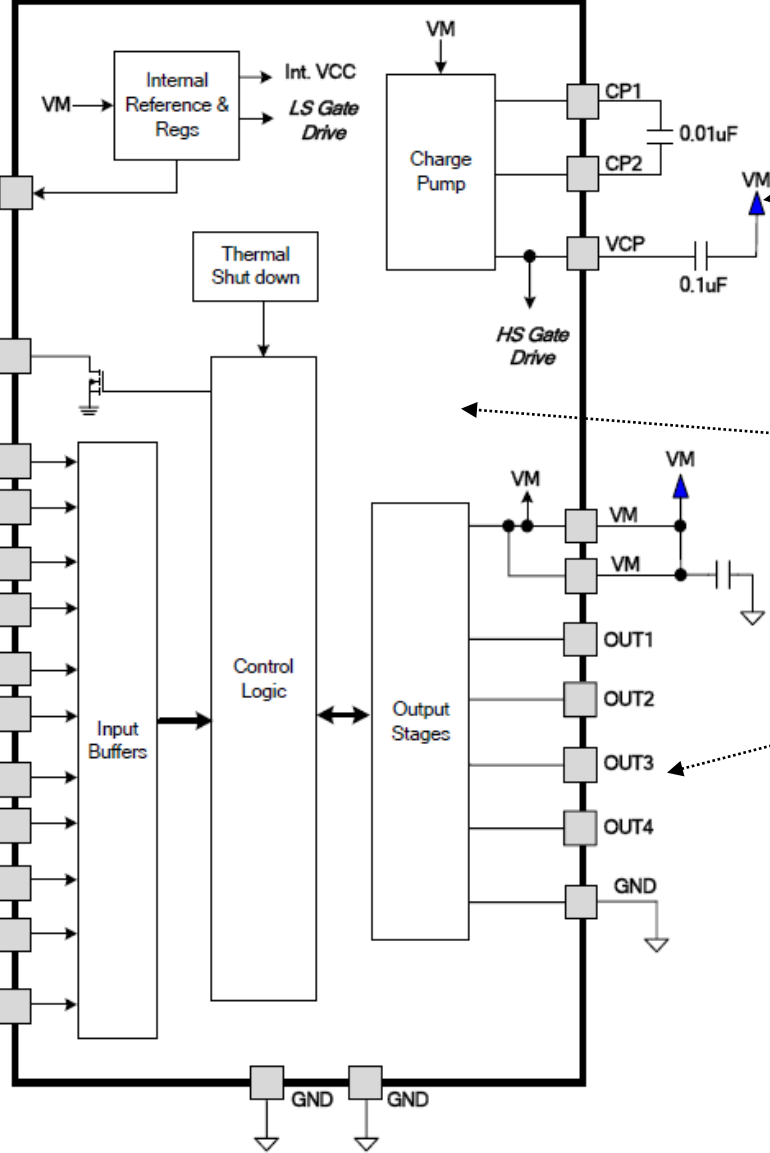
9.7 x 6.4mm, 28接腳 HTSSOP 封裝

TEXAS INSTRUMENTS

DRV8844 Functional Block Diagram
DRV8844 原理框圖

Up to 10mA output
最大10mA負載

Fault flag on all faults. Short circuit auto-retry@128us.
所有報錯都由nFAULT接腳負責。短路情況下每128us後IC會自動重啟

PWM control with independent enables
獨立ENABLE的PWM型接口

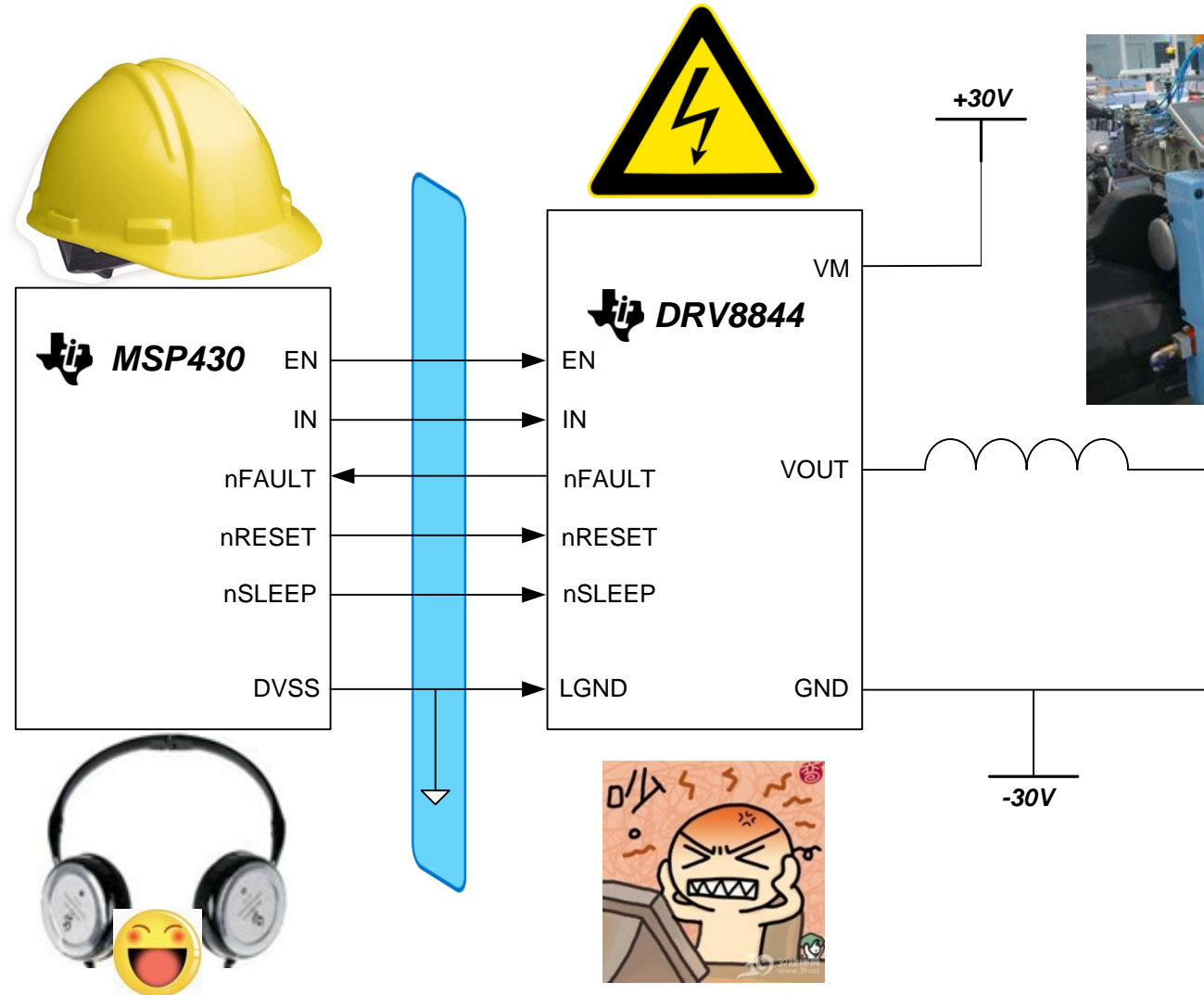| INx	ENx	OUTx
X	0	Z
0	1	L
1	1	H

Logic reference voltage
外接邏輯準位

8.2 to 60V
Supports +24 / -24V split rail operation
可驅動雙極性負載
(VM=+24V, GND=-24V, LGND=0）

Short Circuit, Overtemp, and UVLO protection
短路、過熱及欠壓閉鎖保護

1.75A continuous
2.5A peak per output
400mΩ total Rdson

Internal Reference & Regs
Int. VCC
LS Gate Drive
VM
V3P3OUT
CP1
CP2
VCP
0.01uF
0.1uF
Charge Pump
VM
HS Gate Drive
Thermal Shut down
nFAULT
IN1
EN1
IN2
EN2
IN3
EN3
IN4
EN4
nRESET
nSLEEP
LGND
Input Buffers
Control Logic
Output Stages
VM
VM
OUT1
OUT2
OUT3
OUT4
GND
GND
GND

Selective Disclosure

TEXAS INSTRUMENTS

"Split Rail" Isolates Noise for Controller
分立地線為外部控制器隔離噪音

MSP430		DRV8844	
EN	→	EN	VM → +30V
IN	→	IN	
nFAULT	←	nFAULT	VOUT
nRESET	→	nRESET	
nSLEEP	→	nSLEEP	
DVSS	→	LGND	GND → -30V

TEXAS INSTRUMENTS

DRV8x Stepper Motor Drivers
DRV8x 系列步進馬達驅動器

DRV8412
(6A @ 0 – 50V)

DRV8432
(12A @ 0 – 50V)

High current / performance

DRV8811
(1.9A @ 8 to 38V)
1/8 -ustep

DRV8818
(2.5A @ 8 to 35V)
1/8 -ustep

DRV8824
(1.6A @ 8.2 to 45V)
1/32-ustep

DRV8825
(2.5A @ 8.2 to 45V)
1/32-ustep

Up to 32-μsteps (indexers)

DRV8812
(1.6A @ 8.2 – 45V)

DRV8813
(2.5A @ 8.2 – 45V)

Up to 256 μsteps and Greater

DRV8833
(2A @ 2.7 – 10.8V)
Full and half step

DRV8834
(2.2A @ 2.5 – 10.8V)
1/32-ustep

Low Voltage Steppers

P2P Compatible

Production

Sampling

Selective Disclosure

TEXAS INSTRUMENTS

DRV8x Brushed DC Motor Drivers
DRV8x 系列有刷直流馬達驅動器

New Arrivals!!

DRV8844
5A, 8 to 60V, 10mA LDO
PWM I/F

DRV8837
1.8A, 1.8 to 11V, PWM I/F

DRV8836
2x1.5A /1x3A, 2 to 7V, PWM

DRV8835
2x1.5A /1x3A, 2 to 11V, PWM

DRV8833
2x2A /1x4A, 2.5 to 10.8V, PWM

DRV8832
1A, 2.75 to 6V, IN1/IN2 I/F

DRV8830
1A, 2.75 to 6V, Serial I/F

DRV8432
24A, 0 to 52V, Heatsink, PWM I/F

DRV8412
12A, 0 to 52V, PWM I/F

DRV8842
5A, 8.2 to 45V, PWM I/F

DRV8840
5A, 8.2 to 45V, Phase/Enable

DRV8801
2.2A, 8 to 36V, Phase/Enable

P2P

DRV8800
2.2A, 8 to 36V, Phase/Enable

DRV8844
2.5A, 8 to 60V, 10mA LDO
PWM I/F

DRV8432
12A, 0 to 52V, Heatsink
PWM I/F

DRV8412
6A, 0 to 52V, PWM I/F

DRV8843
2.5A, 8.2 to 45V, PWM I/F

DRV8814
2.5A, 8.2 to 45V, Phase/Enable

P2P

DRV8802
1.6A, 8.2 to 45V, Phase/Enable

DRV8823
1.5A, 8 to 32V, Serial I/F

Low Voltage   Single Brushed   Dual Brushed   Quad Brushed

Selective Disclosure

DRV8x Solenoid / Relay Drivers
DRV8x 系列螺線管/繼電器 驅動器

New Arrivals!!

No catch/freewheel diode required!
無需續流二極管！

DRV8844
2 x 5A, 8 to 60V, 10mA LDO
PWM I/F

DRV8844
4 x 2.5A, 8 to 60V, 10mA LDO
PWM I/F

DRV8432
2 x 14A, 0 to 52V, Heatsink
PWM I/F

DRV8806
4 x 1A, 8.2 to 40V, Serial I/F,
Open Load Detect

DRV8841
4 x 1.75A, 8.2-45V, PWM I/F

DRV8412
2 x 6A, 0 to 52V, PWM I/F

DRV8804
4 x 1A, 8.2 to 60V, Serial I/F

DRV8432
4 x 7A, 0 to 52V, Heatsink
PWM I/F

DRV8842
2 x 3.5A, 8.2 to 45V, PWM I/F

DRV8803
4 x 1A, 8.2 to 60V, PWM

DRV8412
4 x 3A, 0 to 52V, PWM I/F

Dual Drivers

Quad Drivers

Selective Disclosure

TEXAS INSTRUMENTS

DRV8x Low Voltage Motor Drivers
DRV8x 系列低電壓馬達驅動器

Battery Powered Applications
低壓電池應用

Brushed DC

DRV8830
DRV8832
- 1A (2.75 to 6.8V)
- Voltage Regulation
- IN1/IN2 or I2C I/F

DRV8833
- Single: 4A (2.7 to 10.8V)
- Dual: 2 x 2A
- PWM Ctrl

DRV8835
- Single: 3A (2.0 to 11V)
- Dual: 2 x 1.5A
- Dual Supplies
- Phase Enable or PWM Ctrl

New

DRV8836
- Single: 3A (2.0 to 7V)
- Dual: 2 x 1.5A
- Phase Enable or PWM Ctrl

New

DRV8837
- 1.8A (1.8 to 11V)
- Dual Supplies
- PWM Ctrl

New

DRV8851
- 1.8A (1.8 to 11V)
- Dual Supplies
- 150mA LDO
- PWM Ctrl

Stepper

DRV8833
- 2A (2.7 to 10.8V)
- Full or half step
- PWM Ctrl

DRV8834
- 2.2A (2.5 to 10.8V)
- 1/32-step indexer
- > 1/32-step with MCU support
- Step/Dir & Phase Enable Ctrl

DRV8835
- 1.5A (2.0 to 11V)
- Dual Supplies
- Full or half step
- Phase Enable or PWM Ctrl

New

DRV8836
- 1.5A (2.0 to 7V)
- Full or half step
- Phase Enable or PWM Ctrl

New

Motor Type

(Products Highlighted in RED are Sampling, and Blue are Roadmap Products)

Selective Disclosure

TEXAS INSTRUMENTS

For More Information:
Motor Solutions Home Page: www.ti.com/motor

Motor Solutions Guide

Selective Disclosure

For More Information:

E2E Forum

http://e2e.ti.com/support/applications/motor_drivers/default.aspx

Thank You!!
感謝大家！！

TANG Zhao/唐釗
Motor Application Team/馬達應用團隊
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Email/電郵：zhao.tang@ti.com

TI Spins Motors

TEXAS INSTRUMENTS

Smarter. Safer. Greener.

Backup

TI Spins Motors

Smarter. Safer. Greener.

Analog Motor Drive Roadmap

Motor Type (vertical axis label)

3-Phase Brushless
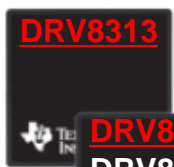
DRV8313
- 3-Phase Driver
- 2.5A (8 to 60)

DRV8815 / DRV8817
- Controller + Driver
- 3A ('15) / 4.8A ('17) (10 to 32V)
- Sine/Trap /Speed Loop

DRV8712
- Controller + PreDriver
- 10 to 32V
- Sine/Trap/Speed Loop

DRV88xx
- Controller + Driver
- Sensorless

Stepper Brushed

DRV8844
- Stepper/Brushed
- 2.5A (8 to 60V)
- Split Rail Support

DRV8806
- Unipolar driver
- Open load detect
- 2A (8-40V)

DRV8711
- Stepper Pre-driver (8 to 52V)
- Stall detection
- 1/256 micro-stepping

Low Voltage

DRV8837 / DRV8851
- Single Brushed DC
- 1.8A (2 to 11V)
- DRV8851 adds 150mA LDO

Special Purpose

DRV9xxx
- Power tool focus
- Brushed DC Pre-Drive
- Integrated state machine

Selective Disclosure

TEXAS INSTRUMENTS

Brush DC Motor Speed-Torque Curves
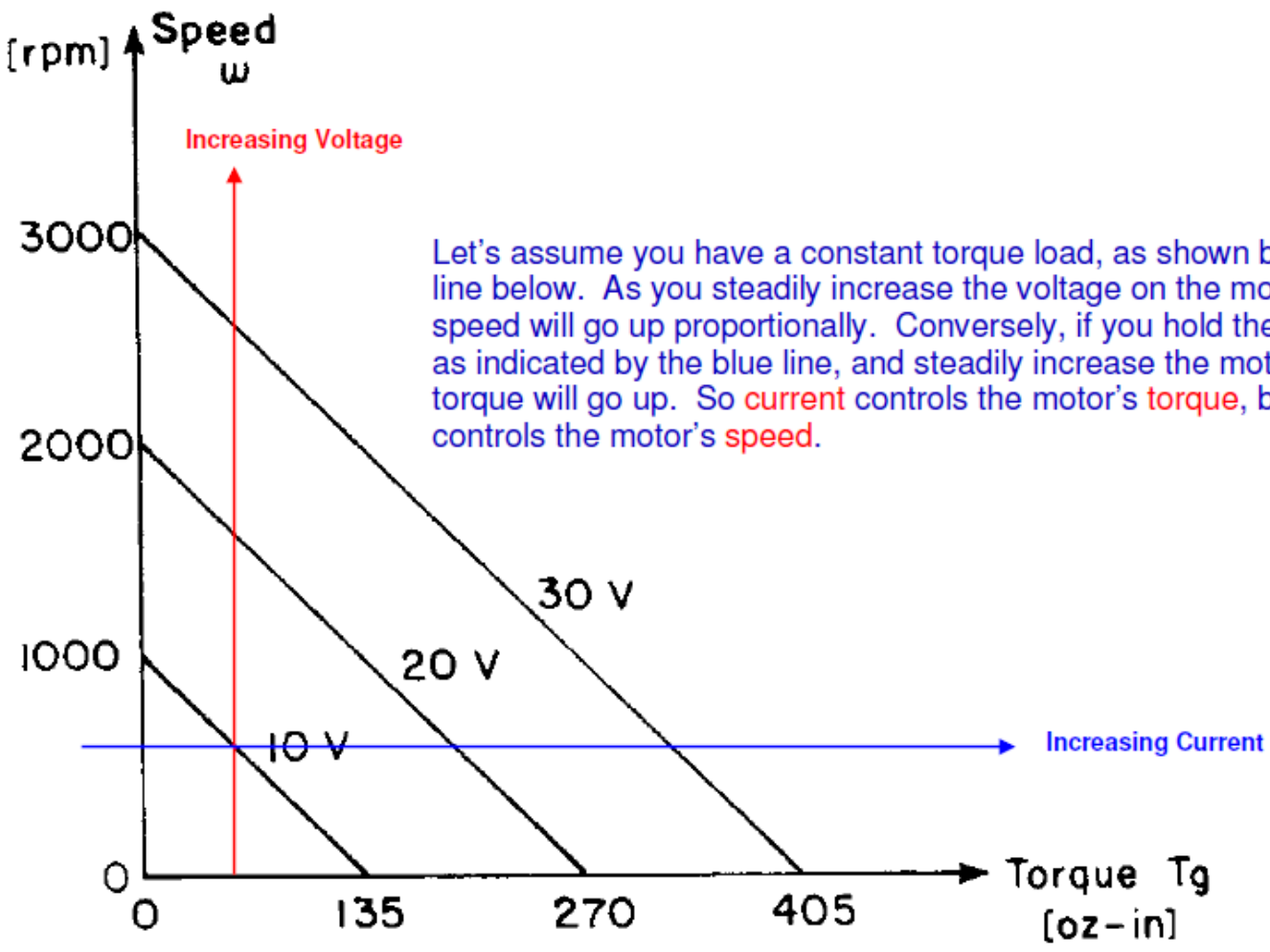
Let's assume you have a constant torque load, as shown by the red vertical line below. As you steadily increase the voltage on the motor terminals, the speed will go up proportionally. Conversely, if you hold the speed constant as indicated by the blue line, and steadily increase the motor's current, the torque will go up. So current controls the motor's torque, but voltage controls the motor's speed.

Speed-torque curves for terminal voltages of 10, 20, and 30 V.

TEXAS INSTRUMENTS

DC Motor Model - Startup

t0

$I_M = 0$

$R_M * I_M = 0$ R_M

$+$
V_S L_M
$-$

V_S

$B_{EMF} = 0$

B_{EMF}

$$V_S = L \, di/dt$$

t0 +

$I_M > 0$

$R_M * I_M > 0$ R_M

L_M

V_S

$B_{EMF} = 0$

B_{EMF}

$$V_S = R_M I_M + L \, di/dt$$

>> t0

$I_M > 0$

$R_M * I_M > 0$ R_M

L_M

V_S

$B_{EMF} > 0$

B_{EMF}

$$V_S = R_M I_M + L \, di/dt + V_{EMF}$$
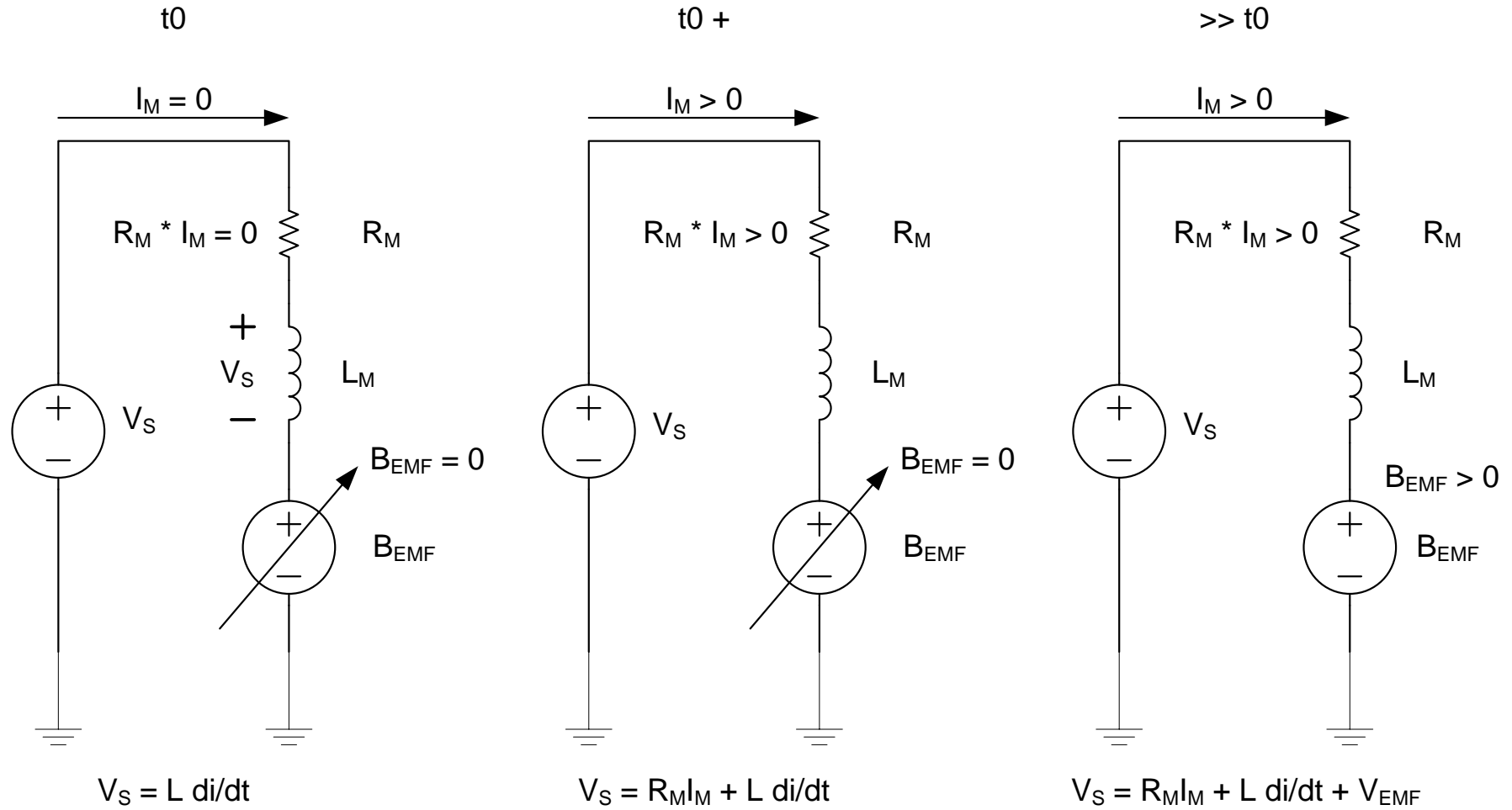
DC Motor Model – Stall Current

Motor Stall State:

- Motor can not move, due to very high load
  - BEMF becomes 0V
- Inductance saturated
  - L*di/dt becomes 0V.
- Current will be a factor of motor resistance.
- IM = VS/RM

$VR_M = V_S$ R_M

$L\, di/dt = 0$

L_M

V_S

$B_{EMF} = 0$

B_{EMF}

I_M

$$V_S = R_M I_M$$
$$I_M = V_S / R_M$$

TEXAS INSTRUMENTS

DRV8818 vs. Allegro's A3979, Rohm's BD63860 Competitive Comparison

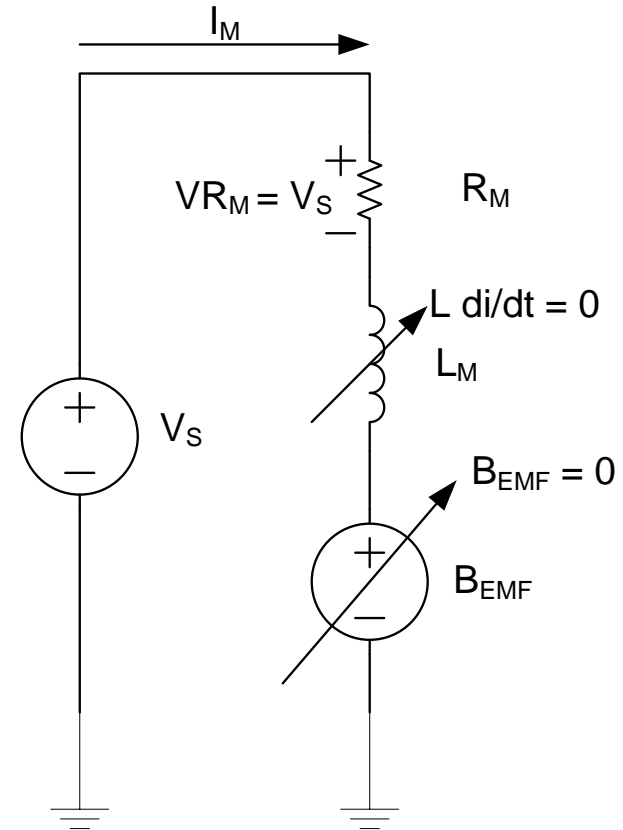| Specification	DRV8818	BD63860	A3977	A3979	LV8731V
Rdson, typical	**0.37 Ω HS+LS**	0.80 Ω HS+LS	0.81 Ω HS+LS	0.50 Ω HS+LS	0.55Ω (at 2A)
Operating Voltage(s)	Vm - 8 to 35V	Vm - 16 to 28V	Vm - 8 to 35V	Vm - 8 to 35V	32V
	Vcc - 3 to 5.5V	Vcc - 3 to 5.5V	Vcc - 3 to 5.5V	Vcc - 3 to 5.5V	9～32V
Thermal Comparison	**Runs Cooler!**	Runs hotter	Runs hotter	Runs hotter	Runs hotter
Sleep Current	3.5uA, typical	400uA, typical	typical not stated	typical not stated	typical not stated
	40uA max	2mA max	20uA max	20uA max	50uA max
Micro-stepping	full-, half-, quarter-, and eighth-step	full-, half-, quarter-, and eighth-step	full-, half-, quarter-, and eighth-step	full-, half-, quarter-, and sixteenth-step	full-, half-, quarter-, and eighth-, sixteen step
Protection	**OCP**, OTS, UVLO, cross-conduction	OTS, No OCP,cross-conduction	OTS, UVLO, No OCP,cross-conduction	OTS, UVLO, No OCP,cross-conduction	OTS, **No OCP, Short Circle Protector** (Latch or Reset function)
Package(s)	28-HTSSOP (P2P)	28-HTSSOP (P2P)	28-HTSSOP (P2P)	28-HTSSOP (P2P)	**SSOP44K** 15.0×7.6×1.7mm
Cost	$2.40 @ 1ku	$3.75 @ 1ku	$2.95 @ 1ku	$4.00 @ 1ku	25RMB
Replacement Code		Q: SAME FUNCTIONALITY AND PINOUT but NOT an exact equivalent.			Two interface can selection

Selective Disclosure

TEXAS INSTRUMENTS

DRV8818 / DRV8825 / DRV8811 / DRV8824 Stepper Motor Driver Selection Guide

Specification	DRV8818	DRV8825	DRV8811	DRV8824
Rdson, typical	0.22 Ω HS + 0.15 Ω LS	0.20 Ω HS + 0.20 Ω LS	0.50 Ω HS + 0.50 Ω LS	0.63 Ω HS + 0.65 Ω LS
Operating Voltage(s)	Vm - 8 to 35V Vcc - 3 to 5.5V	Vm – 8.2 to 45V Single supply	Vm - 8 to 38V Vcc - 3 to 5.5V	Vm – 8.2 to 45V Single supply
Max current before OCP	> 3.5A	> 3A	> 2.5A	> 1.8A
Micro-stepping	full-, half-, quarter-, and eighth-step	Up to 1/32 with indexer; More with external reference	full-, half-, quarter-, and eighth-step	Up to 1/32 with indexer; More with external reference
Current Regulation	Fixed off time More configurable	Fixed frequency, Fewer passives	Fixed off time More configurable	Fixed frequency, Fewer passives
Protection	OCP, OTS, UVLO, cross-conduction	OCP, OTS, UVLO, cross-conduction	OCP, OTS, UVLO, cross-conduction	OCP, OTS, UVLO, cross-conduction
Package(s)	28-HTSSOP (P2P with DRV8811)	28-HTSSOP (P2P with DRV8824)	28-HTSSOP (P2P with DRV8818)	28-HTSSOP (P2P with DRV8825)
Cost	$2.40	$2.40	$1.80	$1.65

Roadmap

DRV8837 vs. Competition:

Specifications	TI DRV8837	Allegro A3903	Allegro A3906	On-Semi (Sanyo) LV8417CS
Motor Type	Brushed DC (Single H-Bridge)	Brushed DC (Single H-Bridge)	Stepper or Brushed (Dual H-Bridge)	Brushed DC (Single H-Bridge)
Motor Supply Voltage	1.8 To 11V	3 to 5.5V	2.5 to 9V	2.0 to 10.5V
Dual Supply Support	Yes	No	No	Yes
RMS Current	1.8A	500mA	2A when outputs are paralleled	1A
Peak Current	1.8A	500mA	2.5A when outputs are paralleled	2.0A (100ms) / 3.8A (10ms)
RDSON (LS + HS)	280mΩ	1.45Ω	~ 570mΩ (outputs paralleled)	270mΩ
Sleep Current (Max)	120nA @ 5V	500nA	500nA @ 5V	1uA
Control I/F	PWM	PWM	PWM	PWM
Inrush current protection	No	No	Yes (Itrip =0.2/Rs)	No
On-Chip Voltage Regulation	No	Yes : Output = 4 x VREF(R1/[R1+R2])	No	No
Protection	Short circuit, thermal, & UVP	No short circuit	No short circuit	No short circuit
Package	8-Pin WSON (2 x 2mm) (4mm2)	8-Pin DFN (2 x 2mm) (4mm2)	20-Pin QFN (4 x 4mm)(16mm2)	9-ball (1.47 x 1.47mm) (2.16mm2)
Pricing, 1k Units	$0.45	$0.45	~ $0.80	~ $1.75

Selective Disclosure

Success Stories: DRV8837
Remote Control Airplane (Toys)

Where We Won

Who: Major Asian Toy Manufacture

What: DRV8837

Where: Aileron / Flaps / Rudder control

Volume: > 1Mu

How We Won

We knocked out a low cost discrete solution due to significant board space savings that helped reduce airplane size and weight, extended battery life (due to low RDSON / low sleep current), and aggressive pricing.
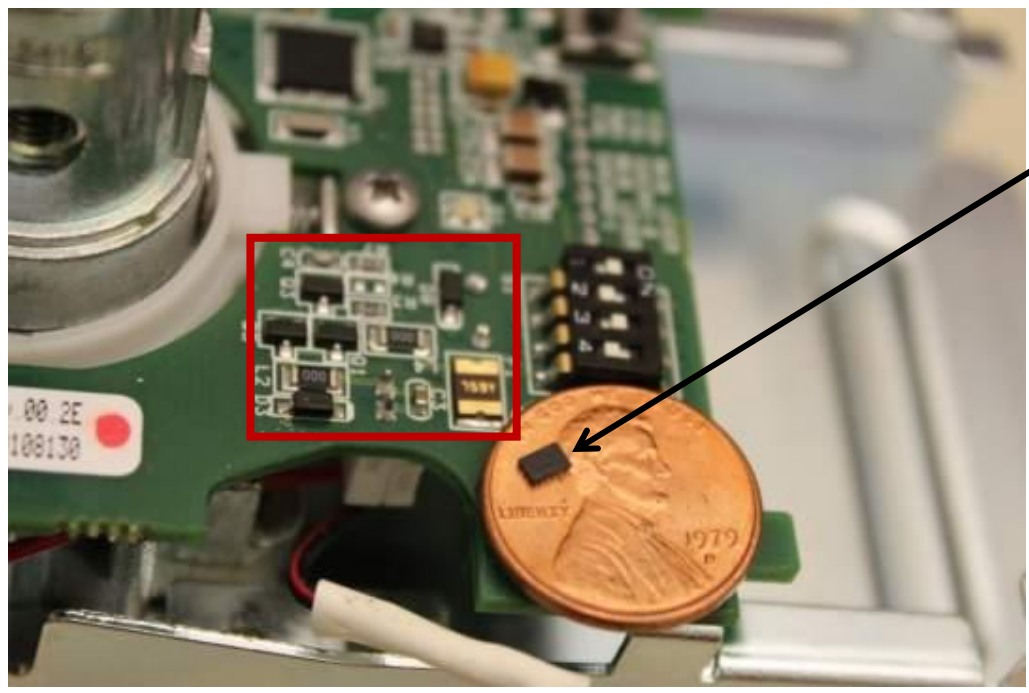
MCU → DRV8837 →

TEXAS INSTRUMENTS

DRV8x vs. Discretes:

DRV8x wins on size, protection, embedded intelligence, and cost competitiveness

3 Amps out of 2 x 3mm package!!

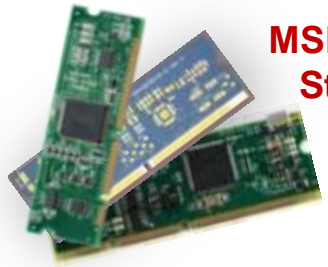**DRV8835:**
- Fully protected
- 20x smaller
- Cost competitive

And Don't forget Assembly Cost!!

TEXAS INSTRUMENTS

DRV8x Motor Kits

MSP430™
Stellaris®
C2000™

DRV8312-C2-KIT

DK-LM3S-DRV8312

DRV8833EVM

DRV8825EVM

DRV8301-HC-C2-KIT

InstaSPIN™
BLDC

InstaSPIN™
FOC

DRV8412-C2-KIT