Welcome!
Texas Instruments New Product Update

- This webinar will be recorded and available at www.ti.com/npu
- Phone lines will be muted
- Please post questions in the chat or contact your sales person or field applications engineer

TI Motor Drivers

Overcome industrial design challenges with stepper motor drivers

Texas Instruments

Introduction

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Agenda

- Types of applications needing mid voltage steppers
- System requirements
- Common stepper motor driver design challenges
- Portfolio overview
- Deep dive on how to solve common design challenges with stepper motor drivers
- Open questions/discussion

Stepper motor driver applications

IVD

Smart Locks

IP Network Camera

Printers

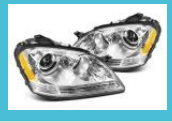
Textiles

ATMs

EPOS Printers

3D printers

Headlight



Smart Sanitation

Hospital Beds

Appliances

Window Blinds

Coffee Machines

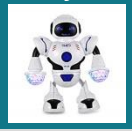
Smart Meters

Power Seats

Vacuum Robot

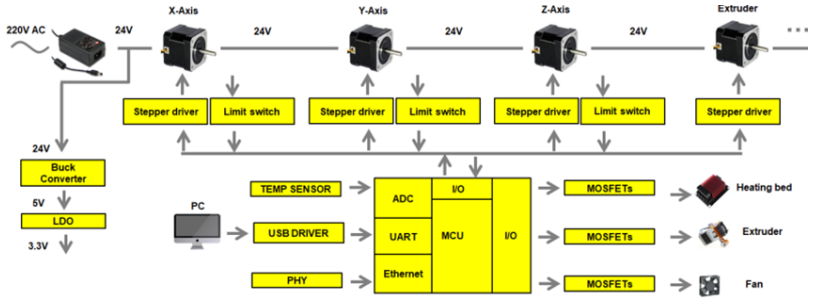
On-board Chrager

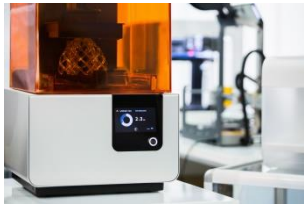
Toys



Head Up Display

System requirements



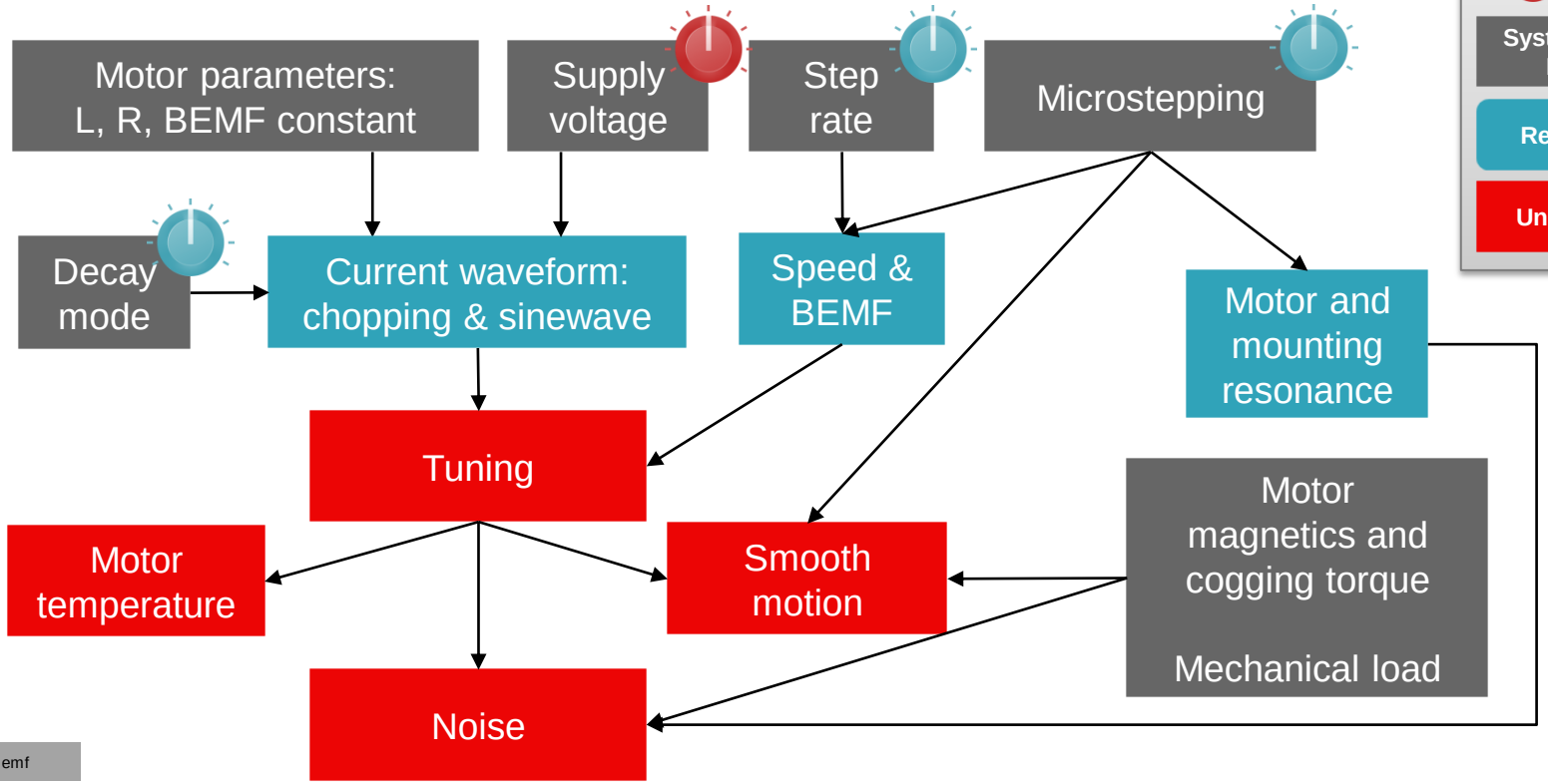


- **Low audio noise (Must have)**
  - Quiet operation is critical, ready to pay more for quiet drivers.
- **High position accuracy and low vibration (Must have)**
  - High accuracy and less vibration are critical for FDM process.
- **Great thermal (Must have)**
  - Eliminate use of heatsinks.
- **Small solution area (Must have)**
  - Small-sized QFN package is preferred by few customers, most customers still prefer SOP for thermal reasons.

Stall detection (*Nice to have*):

- High-end models have 3-5 mechanical or photoelectric limit switches.

Common stepper motor driver problems



LEGEND

Driver setting

System setting

System parameters/ Root causes

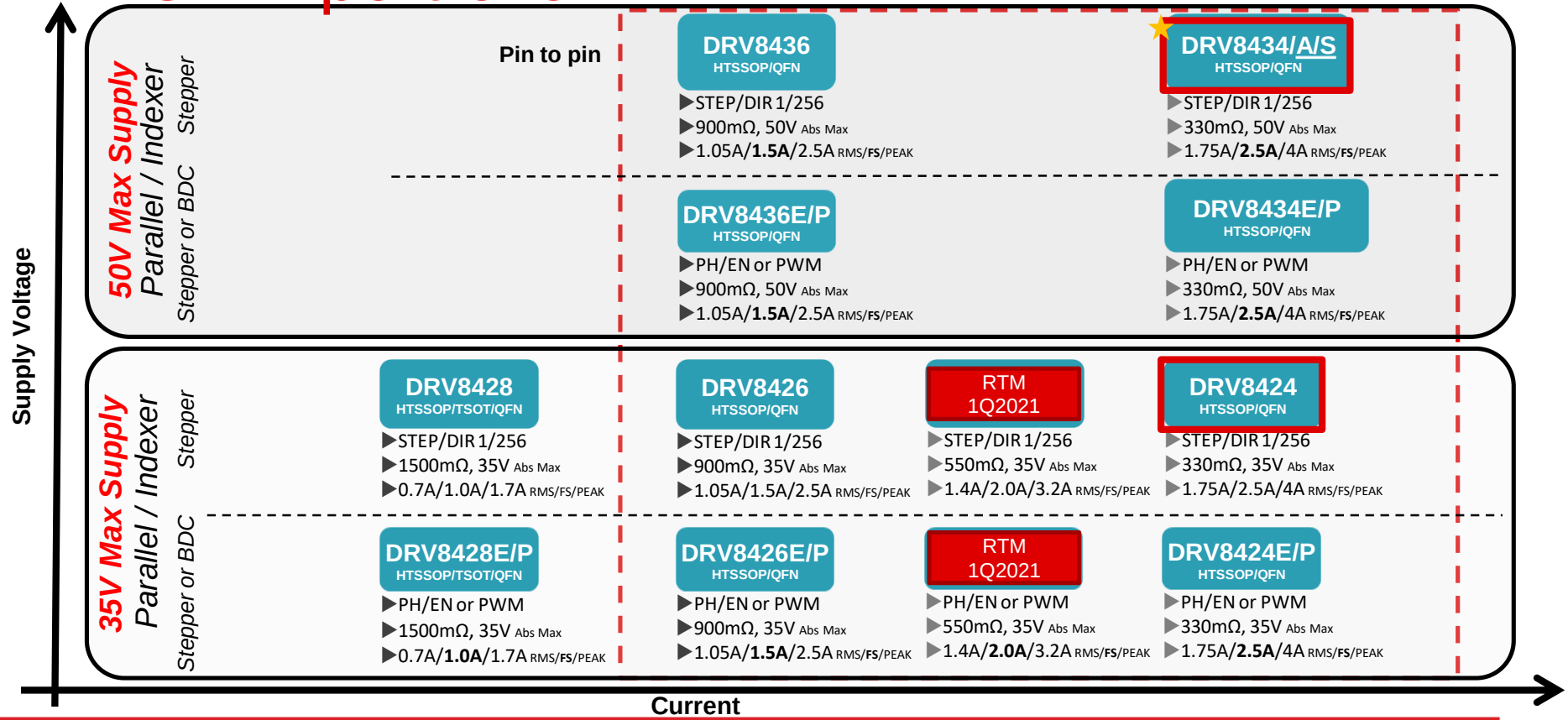
Resulting effects

Undesired results

BEMF: Back emf

DRV84xx portfolio

★ Analog/SPI **Stall** detect version available (**/A/S**) in November



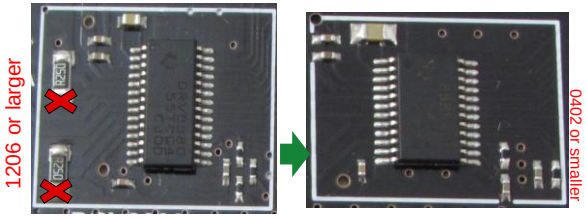
Portfolio overview | Improve motion control using our scalable stepper driver portfolio

Integrated current sensing

Eliminate ***all*** current sense resistors while providing accurate current regulation *(Maximum integration)*

Benefits

- ✓ **BOM reduction:** Removed sense resistors and reduced board size
- ✓ **Power management:** No power loss over the sense resistor
- ✓ **Easy design:** Hassle-free layout with no sense routing

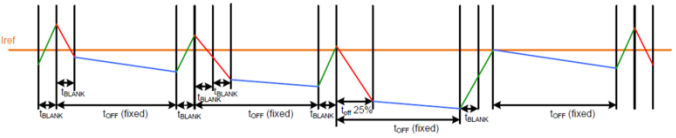


Smart tune

Tune stepper motors effortlessly & automatically *(TI Patented)*

Benefits

- ✓ **Seamless, quiet tuning:** Motor runs quietly without losing regulation
- ✓ **Power management:** Motor runs more efficiently than fixed decay modes
- ✓ **Shorter design cycle:** No need to spend months tweaking decay modes of motors
- ✓ **Reliability:** Auto adjustment to motor parameters over lifetime
- ✓ **Thermal management:** Makes system 5-12 degrees cooler than traditional decay modes
- ✓ **Ripple control:** Automatically adjusts and controls the ripple current level resulting in higher average torque at each step



High microstepping & more

1/256 microstepping with accurate current sense, wide input voltage, low Rdson and protection features

Benefits

- ✓ **Fine microstepping:** 1/256 microstepping for more accurate and controlled motion
- ✓ **Current sense accuracy to ± <5%**
- ✓ **5 level protection:** UVLO, CPUV,OCP, OL, OTSD
- ✓ **P2P scalability in QFN reducing size:**
  - ✓ **Smallest 16 Pin TSOT 3x3mm** package (1.5Ω)
  - ✓ **4x4mm QFN** package with range of RDson options (0.33Ω – 0.9Ω)
- ✓ **Flexibility:**
  - Wide operating voltage range (4.2V - 48V)
  - Simple STEP/DIR, PH/EN and PWM interface

DRV84xx | Improve motion control using our scalable stepper driver portfolio

Features

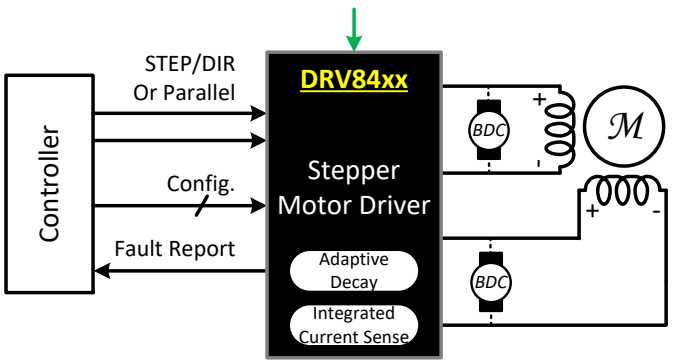
- Dual H bridge stepper motor driver
  - Supply voltage: DRV842x: **4.5 to 33 V (abs max 35 V)**
    DRV843x: **4.5 to 48 V (abs max 50 V)**
  - Current: **RMS: 0.7-1.75A, FS: 1.0-2.5A, Peak: 1.7-4A**
  - RDS(ON): **330 mΩ - 1500 mΩ HS + LS** (at 24 V, 25°C)
- **Integrated current sensing** eliminates 2 current sense resistors!
- Up to 5% Full-scale Current Accuracy and ch-to-ch current matching
- **Smart tune adaptive decay technology**
- Interface Options: STEP/DIR Indexer up to 1/256 microstepping or Parallel interface (PH/EN, PWM)
- **Fully protected**: Supply and charge pump undervoltage, overcurrent protection with latched or retry response, open-load detection, thermal shutdown

Applications

- Multi-function printers
- Laser-beam printers
- Scanners
- Stage lighting
- ATMs & currency counters
- EPOS printers
- Textile machines
- Air purifiers & humidifiers
- IP network camera

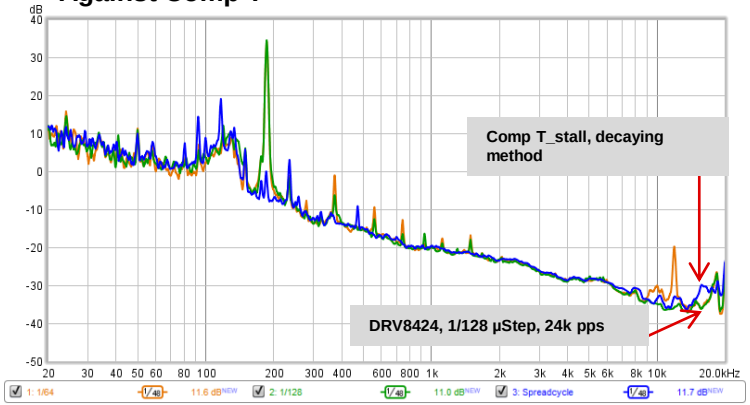
Benefits

- Wide supply range supports industry standard supplies and high output current delivers maximum performance
- Integrated current sense reduces system cost, improves efficiency and makes PCB layout easy
- Small package and simple pinout also results in simple PCB layout
- Accurate and smooth operation without support from the system controller: smother, quieter micro-stepping motion profiles; flexible configuration options
- Advanced on-chip protection reduces design complexity and enables higher system reliability



Reduce audible noise

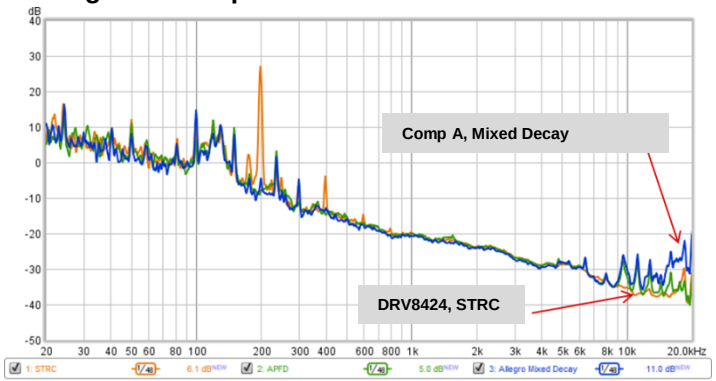
Against Comp T



Comp T_no stall decaying method, 3k pps

DRV8424 STRC at 1/128 µStep, 24k pps

Against Comp A



Comp A_no stall mixed decay, 1.6k pps, 1/16 µStep

DRV8424 STRC at 1/256 µStep, 25.6k pps

By increasing microstepping and by increasing step frequency to > 20 kHz, DRV84xx is:

- Quieter than Comp A (Comp A_no stall)
- Similar to Comp T (Comp T_no stall, Comp T_stall)

Reduce audible noise

Causes of audible noise

- Magnetic noise
- Mechanical noise
- Electrical noise

Methods to reduce audible noise (electrical) –

- Low current ripple
- Slow-decay whenever possible
- PWM Switching Frequency higher than 20 kHz
- Smooth Current waveform around zero current
- Step frequency higher than 20 kHz

Advantages of Smart Tune Ripple Control (STRC) Decay Mode

- Low current ripple
  - Ripple can be tightly regulated to ~50mA, compared to ~200mA with m
  - Ensures PWM frequency is beyond 20kHz
- STRC operates with slow decay, and turns on fast decay to transition between
  - Maintains sinusoidal current waveform at any speed
- Smooth current waveform around zero current
- High microstepping (up to 1/256 microstepping)
  - Allows increasing the step frequency to >20kHz by increasing microstepping

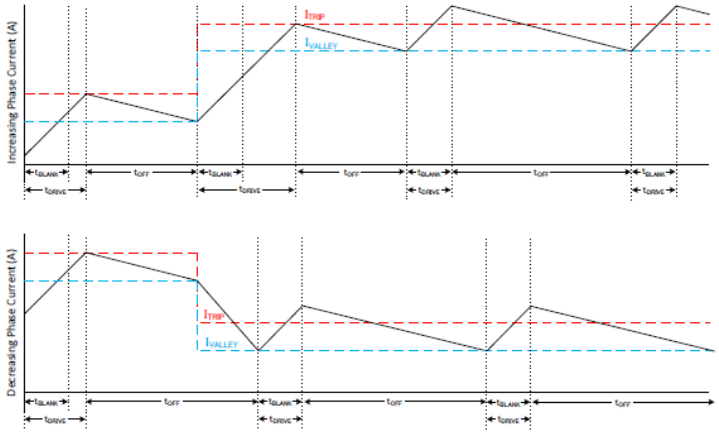


Figure 9. Smart tune Ripple Control Decay Mode

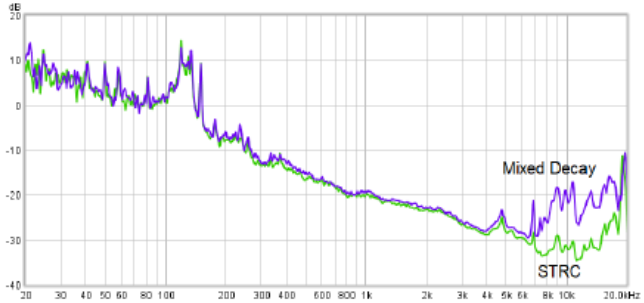


Figure 10. Mixed Decay vs Smart Tune Ripple Control (STRC) at 1/256 Microstepping

Improve stepper motor driver tuning

What is tuning and decay modes?

- Process of recirculation of the winding current in the drive switches or through the diodes once the current 'trip' threshold is reached

Are there limitations of conventional fixed-decay schemes (slow, fast and mixed decay)?

- Sometimes unable to precisely regulate current
- Susceptible to changes in voltage, load current and back emf

What is smart tune?

– Intelligent decay scheme continuously adapts to provide the best possible decay solution

– Types: **Dynamic decay mode & ripple control mode**

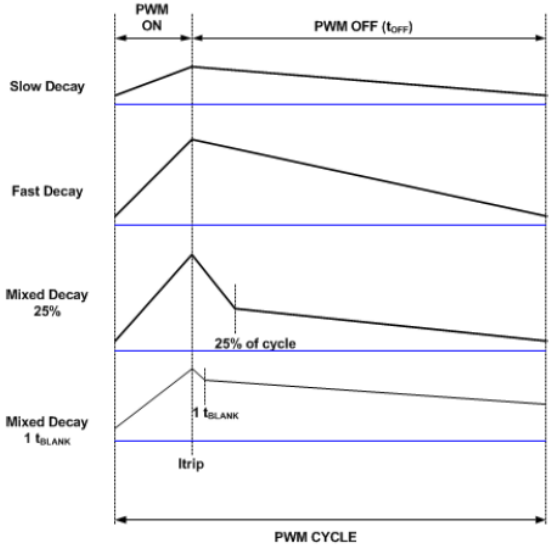


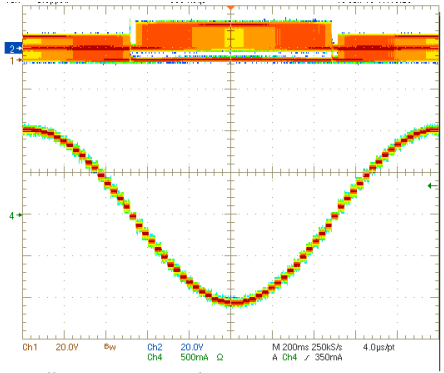
Figure 3. Current waveforms in slow, fast and mixed decay modes

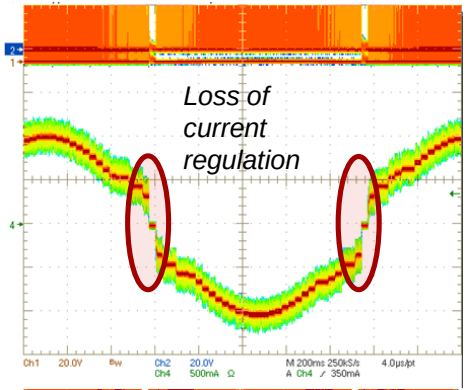
Smart tuning in action

Low Voltage (12V)

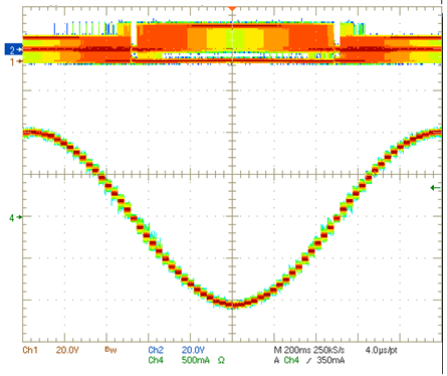
High Voltage (45V)

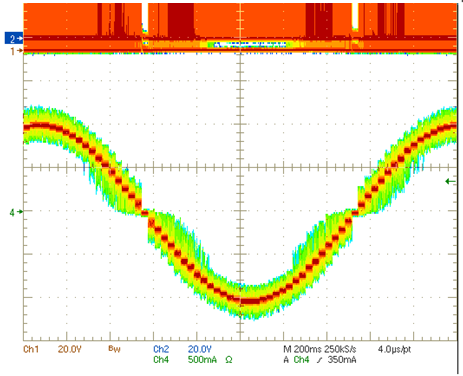
Slow decay





Smart tuning



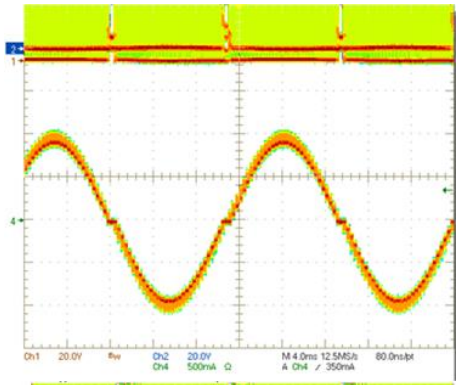


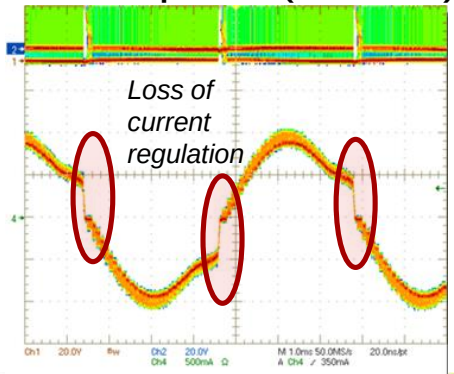
Smart tuning in action

Slow Speed (3 kHz)

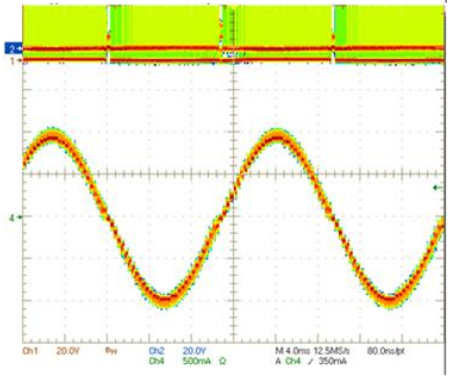
Fast Speed (10 kHz)

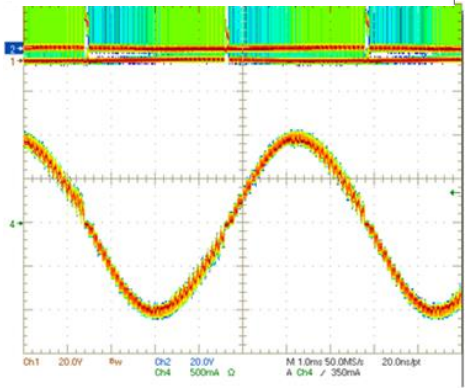
30% mixed decay





Smart tuning





Smart tuning in action

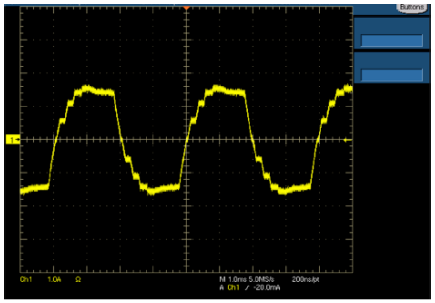


Figure 2. Stepper current waveform running at 4,000 pulses per second using 1/4 microstepping and slow decay on increasing and decreasing steps

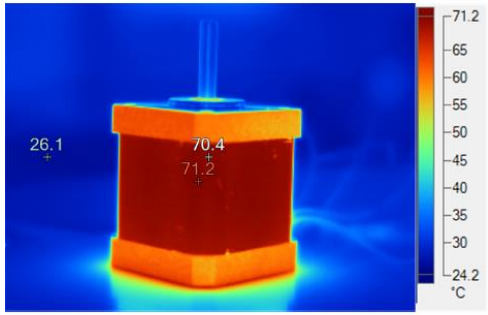


Figure 3. Thermal image after one hour using 1/4 microstepping and slow decay on increasing and decreasing steps

11 ºC cooler!

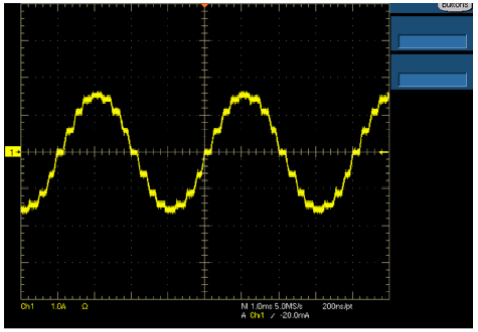


Figure 1. Stepper current waveform running at 4,000 pulses per second using 1/4 microstepping and dynamic decay

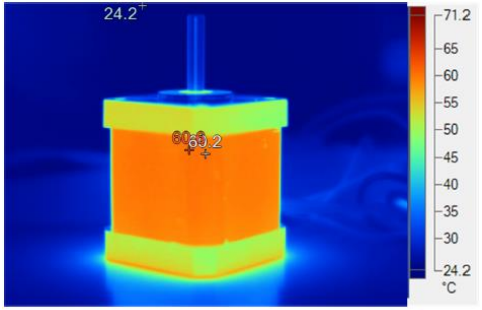
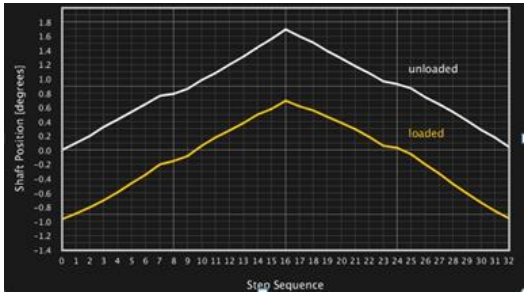


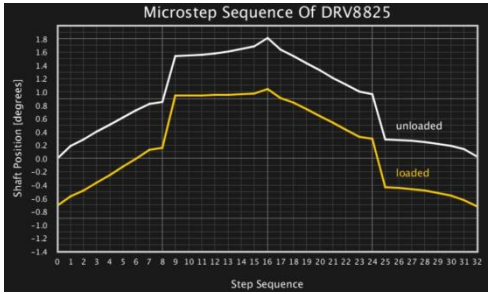
Figure 4. Thermal image after one hour using 1/4 microstepping and dynamic decay on increasing and decreasing steps

Stopping position accuracy

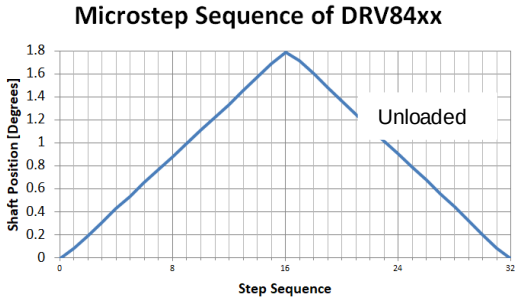
In multiple systems, the quality of motion (smoothness) depends a lot on the **motion accuracy** of the stepper motors controlling movement of the arms and axis in X-Y-Z directions



Position Accuracy of Comp A_no stall, 1/16 µStep



Position Accuracy of DRV8825, 1/16 µStep



Position accuracy of DRV8424 1/16 µStep

- Source of Comp A_no stall and DRV8825 Data
- DRV8424 accuracy has been measured in STRC decay mode

- **DRV8424 has far better accuracy than DRV8825**
- **DRV8424 has better accuracy than Comp A_no stall, at around 0.9°**

Thermal performance comparison

Increase BOM space and cost reduction in applications by using motor drivers with better thermals to lessen heat dissipation and eliminate heat sinks

Device	Typical RdsON at 25°C	Max. RdsON at 25°C	Typical Conduction Loss with 1.5A RMS
Comp A_no stall	0.64	0.86	2.88 W
Comp T_no stall	0.57	0.77	2.57 W
Comp T_stall	0.34	0.42	1.53 W
DRV8825	0.4	0.51	1.8 W
DRV8424	**0.33**	**0.4**	**1.49 W**

Comp A_no stall

DRV8825

Comp T_no stall

- **DRV8424 has lower I^2R loss –**
  - 50% lower than Comp A_no stall,
  - 40% lower than Comp T_no stall
- DRV8825 , Comp A_no stall and Comp T_no stall **require** heat sinks for more than 1A RMS current
  - DRV84xx doesn't need heatsinks!

BOM & EVM solution area comparison

BOM for the same current range

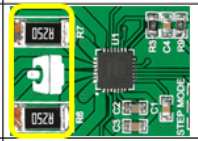
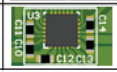
Device	Package	Package Size	No. of resistors in BOM	No. of capacitors in BOM
DRV8424	**QFN-24**	**16 mm²**	**3 (all 0603)**	**5 (all 0603)**
DRV8825	HTSSOP-28	42.68 mm²	0603 resistors x 5 1206 or larger x 2	5 (all 0603)
Comp A_no stall	QFN-28	25 mm²	0603 resistors x 4 1206 or larger x 2	6 (all 0603)
Comp T_no stall	QFN-28	25 mm²	1206 or larger x 2	6 (all 0603)
Comp T_stall	QFN-28	25 mm²	1206 or larger x 2	6 (all 0603)

DRV8424 does not require an external current sense resistor

- Significant area savings
  - Sense resistors are 1206 or larger.
- Significant BOM cost savings
- Power loss savings
  - External sense resistors dissipate I^2R power.

EVM

*drawn to scale

Device	Estimated Solution Dimension and Area	Solution Area Layout
Comp A	25 mm x 18 mm; 450 mm²	
DRV8825	25 mm x 12 mm; 300 mm²	
Comp T (no stall and stall versions)	18 mm x 12 mm; 216 mm²	
DRV8424	**14 mm x 8 mm; 112 mm²**	

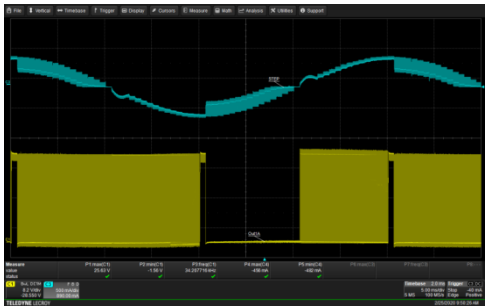
External sense resistor (highlighted) increases the solution area for Comp A_no stall, DRV8825, Comp T_no stall

DRV8424 solution is:

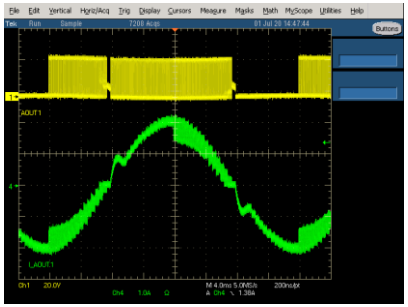
- 75% smaller than Comp A_no stall,
- 60% smaller than DRV8825
- 50% smaller than Comp T_no stall

Current regulation comparison, 1/16 µStepping

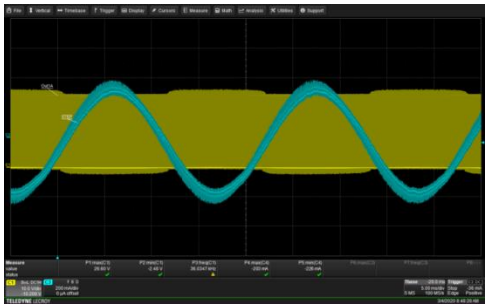
Good current regulation is needed for good motor control and lower ripple



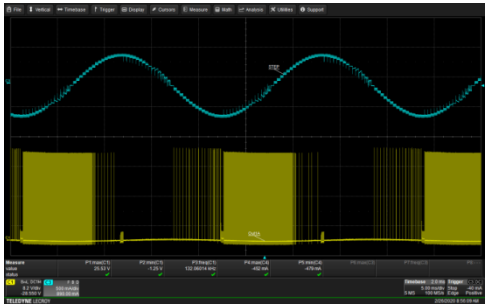
Comp A Comp A_no stall, Slow-mixed decay (30% fast), 24us OFF time



TI old gen DRV8825, Slow-mixed decay (75% fast), 24us OFF time



Comp T Comp T_no stall decaying method



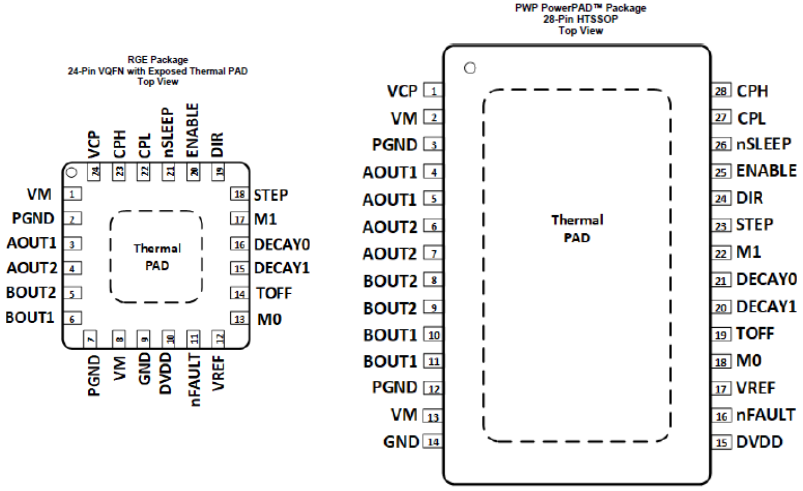
TI new gen DRV8424
Smart tune ripple control

Our portfolio features smart tune ripple control decay mode :

- Lowest ripple current -> ripple is tightly regulated
- Current waveform looks like an ideal sinusoid
- Can adapt itself to low or high speed of motor

Improve board layout

- 2 pins per output for HTSSOP package
  - Easy PCB layout
- Clearly separated power and logic pins
  - Helps with Pin FMEA
- 0.5 mm pitch in QFN, 0.65 mm pitch in HTSSO
  - Meets industrial PCB layout standards
- HTSSOP and QFN package have exposed pads
  - Helps with power dissipation

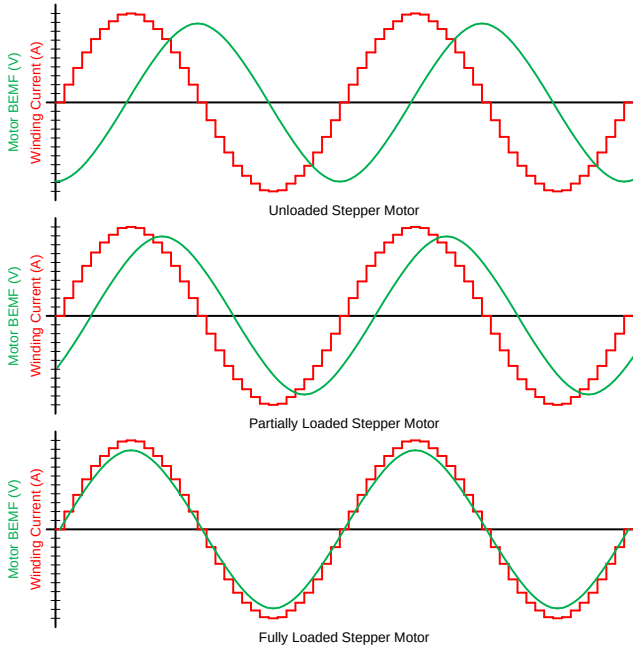


DRV8424 pinout

Detect stall with stepper motor drivers

If a motor reaches end of line or hits a physical obstruction then it can cause the motor to overheat.

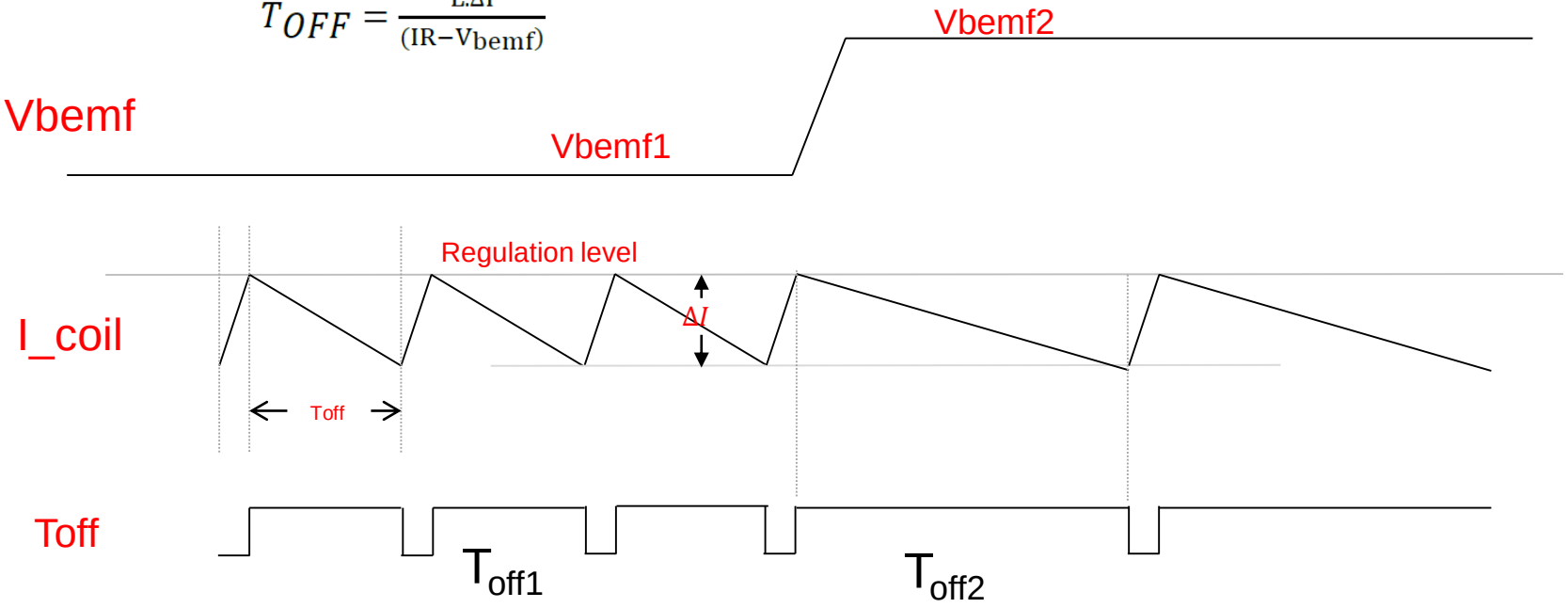
Such condition is called stall condition.



- Stepper motors have a distinct back-EMF relation between the winding current, back-EMF, and mechanical torque load of the motor.
- Any power not consumed due to the mechanical load shows up as a phase shift in the motor back-EMF.
- As motor load approaches the torque capability of the motor at a given winding current, the back-EMF will move in phase with the winding current.
- A motor, when spinning fast, will produce more back-EMF than when spinning slower. And when motor is stalled, there is zero back-EMF produced.
- Thus, by directly measuring back-EMF or by sensing change in back-EMF, it is possible to detect if motor is running or stopped.

Fixed ΔI current regulation (ripple control)

$$T_{OFF} = \frac{L.\Delta I}{(IR - Vbemf)}$$

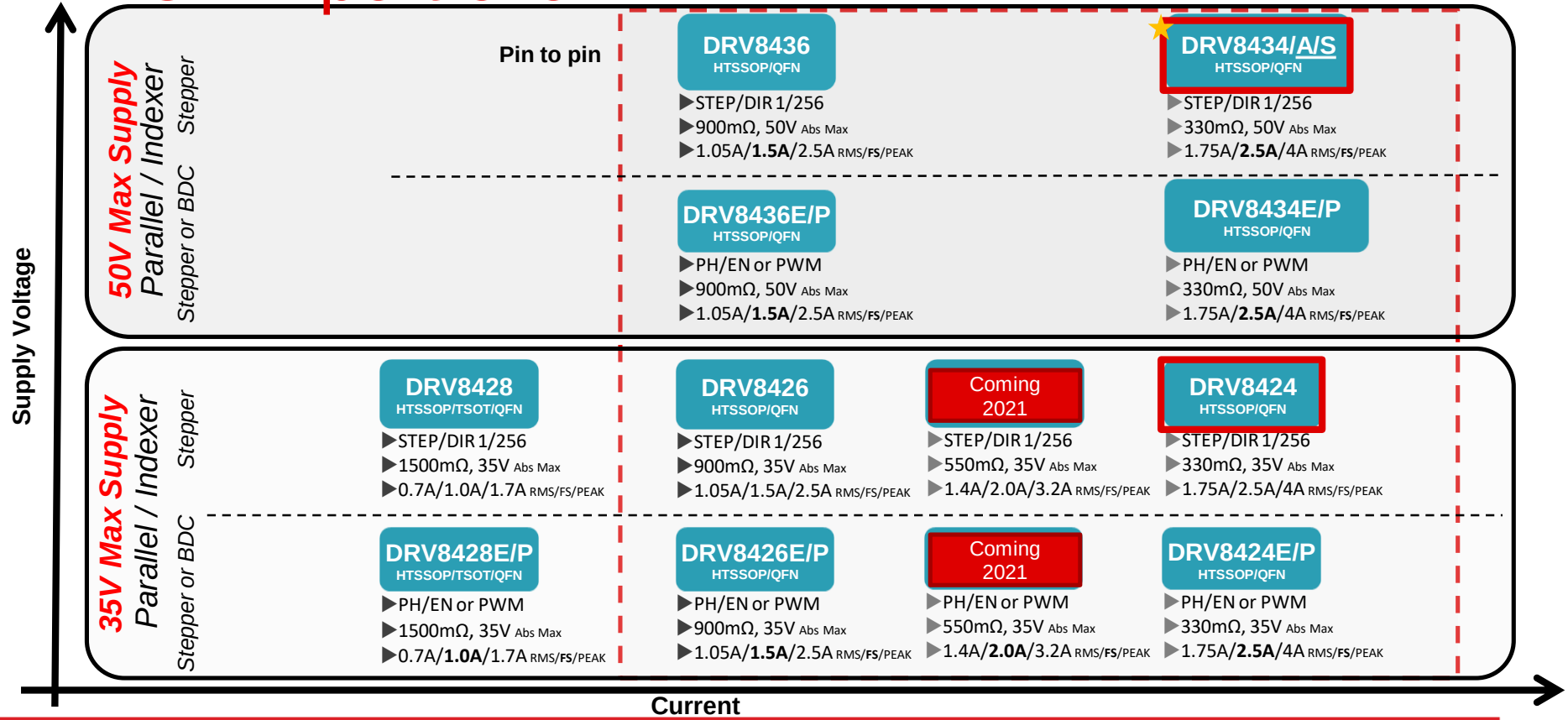


ΔT_{OFF} independent of V_M and IR

$$\frac{1}{T_{off1}} - \frac{1}{T_{off2}} = \frac{1}{L.\Delta I}(V_{bemf2} - V_{bemf1})$$

DRV84xx portfolio

★ Analog/SPI **Stall** detect version available (**/A/S**) in November



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Thank you! Questions?

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