

FAN7388

3 Half-Bridge Gate-Drive IC

Features

- Floating Channel for Bootstrap Operation to +600V
- Typically 350mA/650mA Sourcing/Sinking Current Driving Capability for All Channels
- 3 Half-Bridge Gate Driver
- Extended Allowable Negative V_S Swing to -9.8V for Signal Propagation at $V_{BS}=15V$
- Matched Propagation Delay Time Maximum: 50ns
- 3.3V and 5V Input Logic Compatible
- Built-in Shoot-Through Prevention Circuit for All Channels with 270ns Typical Dead Time
- Built-in Common Mode dv/dt Noise Canceling Circuit
- Built-in UVLO Functions for All Channels

Applications

- 3-Phase Motor Inverter Driver

Description

The FAN7388 is a monolithic three half-bridge gate-drive IC designed for high-voltage, high-speed driving MOS-FETs and IGBTs operating up to +600V.

Fairchild's high-voltage process and common-mode noise canceling technique provide stable operation of high-side drivers under high- dv/dt noise circumstances.

An advanced level-shift circuit allows high-side gate driver operation up to $V_S = -9.8V$ (typical) for $V_{BS} = 15V$.

The UVLO circuits prevent malfunction when V_{DD} and V_{BS} are lower than the specified threshold voltage.

Output drivers typically source/sink 350mA/650mA, respectively, which is suitable for three-phase half-bridge applications in motor drive systems.

20-SOIC



Ordering Information

| Part Number | Package | Operating Temperature Range | Eco Status | Packing Method |
|-------------|---------|-----------------------------|------------|----------------|
| FAN7388M | 20-SOIC | -40°C to +125°C | RoHS | Tube |
| FAN7388MX | | | RoHS | Tape & Reel |

 For Fairchild's definition of "green" Eco Status, please visit: http://www.fairchildsemi.com/company/green/rohs_green.html.

Typical Application Circuit

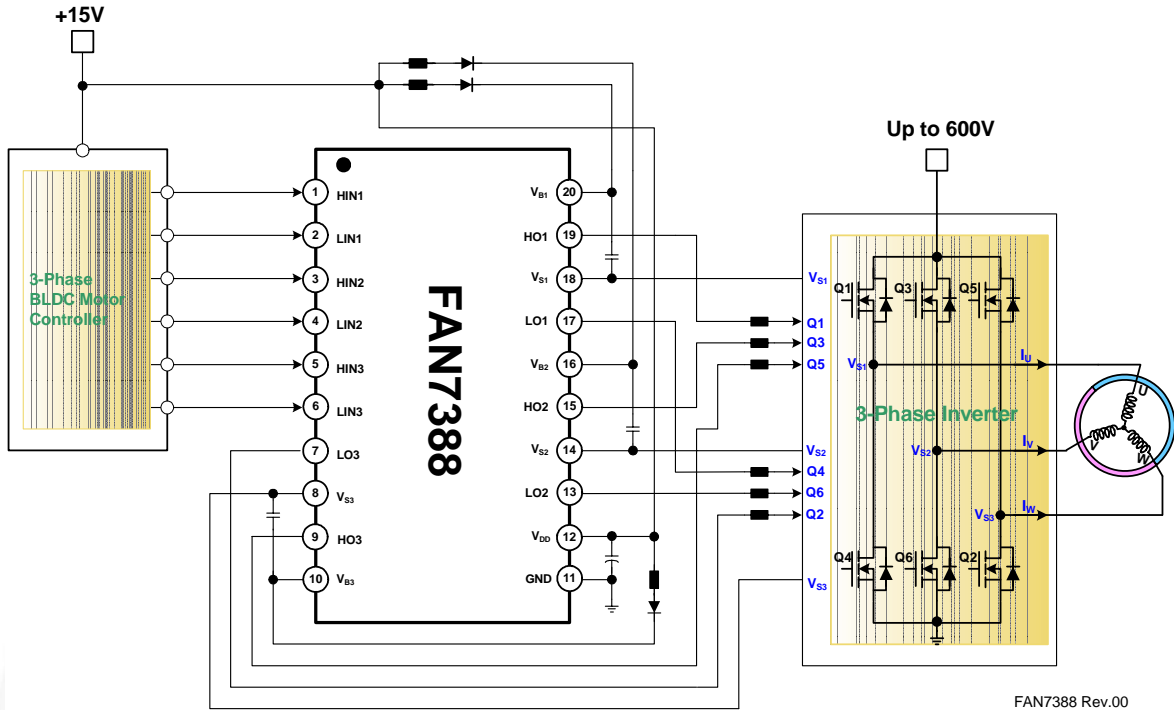


Figure 1. 3-Phase BLDC Motor Drive Application

Internal Block Diagram

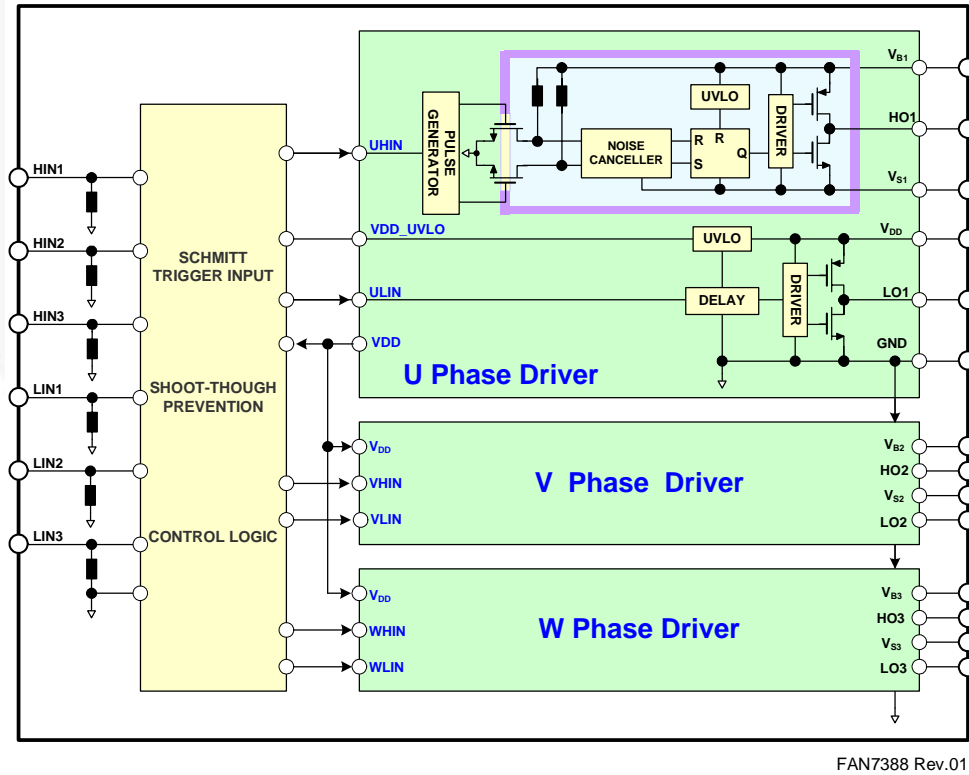


Figure 2. Functional Block Diagram

Pin Configuration

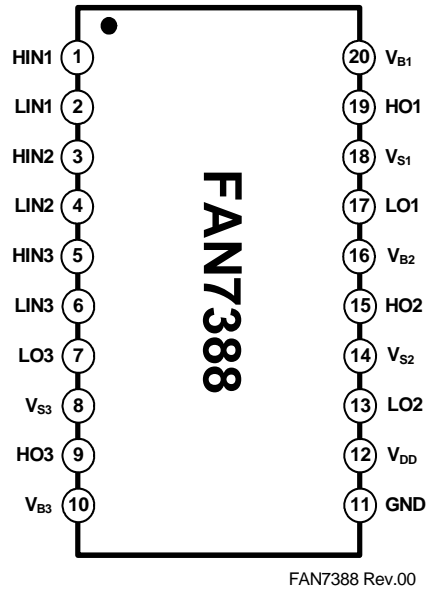


Figure 3. Pin Configuration (Top View)

Pin Definitions

| Pin # | Name | Description |
|-------|-----------------|--|
| 1 | HIN1 | Logic input 1 for high-side gate 1 driver |
| 2 | LIN1 | Logic input 1 for low-side gate 1 driver |
| 3 | HIN2 | Logic input 2 for high-side gate 2 driver |
| 4 | LIN2 | Logic input 2 for low-side gate 2 driver |
| 5 | HIN3 | Logic input 3 for high-side gate 3 driver |
| 6 | LIN3 | Logic input 3 for low-side gate 3 driver |
| 7 | LO3 | Low-side gate driver 3 output |
| 8 | V _{S3} | High-side driver 3 floating supply offset voltage |
| 9 | HO3 | High-side driver 3 gate driver output |
| 10 | V _{B3} | High-side driver 3 floating supply voltage |
| 11 | GND | Ground |
| 12 | V _{DD} | Logic and all low-side gate drivers power supply voltage |
| 13 | LO2 | Low-side gate driver 2 output |
| 14 | V _{S2} | High-side driver 2 floating supply offset voltage |
| 15 | HO2 | High-side driver 2 gate driver output |
| 16 | V _{B2} | High-side driver 2 floating supply voltage |
| 17 | LO1 | Low-side gate driver 1 output |
| 18 | V _{S1} | High-side driver 1 floating supply offset voltage |
| 19 | HO1 | High-side driver 1 gate driver output |
| 20 | V _{B1} | High-side driver 1 floating supply voltage |

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. $T_A=25^{\circ}\text{C}$, unless otherwise specified.

| Symbol | Parameter | Min. | Max. | Unit |
|---------------|--|------------------|------------------|-----------------------------|
| V_B | High-side Floating Supply Voltage of $V_{B1,2,3}$ | -0.3 | 625.0 | V |
| V_S | High-side Floating Supply Offset Voltage of $V_{S1,2,3}$ | $V_{B1,2,3}-25$ | $V_{B1,2,3}+0.3$ | V |
| $V_{HO1,2,3}$ | High-side Floating Output Voltage | $V_{S1,2,3}-0.3$ | $V_{B1,2,3}+0.3$ | V |
| V_{DD} | Low-side and Logic-fixed Supply Voltage | -0.3 | 25.0 | V |
| $V_{LO1,2,3}$ | Low-side Output Voltage | -0.3 | $V_{DD}+0.3$ | V |
| V_{IN} | Logic Input Voltage (HIN1,2,3 and LIN1,2,3) | -0.3 | $V_{DD}+0.3$ | V |
| dV_S/dt | Allowable Offset Voltage Slew Rate | | 50 | V/ns |
| P_D | Power Dissipation ⁽¹⁾⁽²⁾⁽³⁾ | | 1.8 | W |
| θ_{JA} | Thermal Resistance, Junction-to-ambient | | 80 | $^{\circ}\text{C}/\text{W}$ |
| T_J | Junction Temperature | | +150 | $^{\circ}\text{C}$ |
| T_{STG} | Storage Temperature | -55 | +150 | $^{\circ}\text{C}$ |

Notes:

- Mounted on 76.2 x 114.3 x 1.6mm PCB (FR-4 glass epoxy material).
- Refer to the following standards:
 - JESD51-2: Integral circuits thermal test method environmental conditions - natural convection
 - JESD51-3: Low effective thermal conductivity test board for leaded surface-mount packages.
- Do not exceed P_D under any circumstances.

Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Fairchild does not recommend exceeding them or designing to Absolute Maximum Ratings.

| Symbol | Parameter | Min. | Max. | Unit |
|---------------|---|-----------------|-----------------|--------------------|
| $V_{B1,2,3}$ | High-side Floating Supply Voltage | $V_{S1,2,3}+10$ | $V_{S1,2,3}+20$ | V |
| $V_{S1,2,3}$ | High-side Floating Supply Offset Voltage | $6-V_{DD}$ | 600 | V |
| V_{DD} | Supply Voltage | 10 | 20 | V |
| $V_{HO1,2,3}$ | High-side Output Voltage | $V_{S1,2,3}$ | $V_{B1,2,3}$ | V |
| $V_{LO1,2,3}$ | Low-side Output Voltage | GND | V_{DD} | V |
| V_{IN} | Logic Input Voltage (HIN1,2,3 and LIN1,2,3) | GND | V_{DD} | V |
| T_A | Ambient Temperature | -40 | +125 | $^{\circ}\text{C}$ |

Electrical Characteristics

V_{BIAS} (V_{DD} , $V_{BS1,2,3}$)=15.0V, $T_A=25^\circ\text{C}$, unless otherwise specified. The V_{IN} and I_{IN} parameters are referenced to GND. The V_O and I_O parameters are referenced to GND and $V_{S1,2,3}$ and are applicable to the respective outputs LO1,2,3 and HO1,2,3.

| Symbol | Characteristics | Condition | Min. | Typ. | Max. | Unit |
|--|---|---|------|------|------|------------------|
| LOW-SIDE POWER SUPPLY SECTION | | | | | | |
| I_{QDD} | Quiescent V_{DD} Supply Current | $V_{LIN1,2,3}=0\text{V}$ or 5V | | 160 | 350 | μA |
| $I_{PDD1,2,3}$ | Operating V_{DD} Supply Current for each Channel | $f_{LIN1,2,3}=20\text{kHz}$, rms Value | | 500 | 900 | μA |
| V_{DDUV+} | V_{DD} Supply Under-Voltage Positive-going Threshold | $V_{DD}=\text{Sweep}$, $V_{BS}=15\text{V}$ | 7.2 | 8.2 | 9.0 | V |
| V_{DDUV-} | V_{DD} Supply Under-Voltage Negative-going Threshold | $V_{DD}=\text{Sweep}$, $V_{BS}=15\text{V}$ | 6.8 | 7.8 | 8.5 | V |
| V_{DDHYS} | V_{DD} Supply Under-Voltage Lockout Hysteresis | $V_{DD}=\text{Sweep}$, $V_{BS}=15\text{V}$ | | 0.4 | | V |
| BOOTSTRAPPED POWER SUPPLY SECTION | | | | | | |
| $I_{QBS1,2,3}$ | Quiescent V_{BS} Supply Current for each Channel | $V_{HIN1,2,3}=0\text{V}$ or 5V | | 50 | 120 | μA |
| $I_{PBS1,2,3}$ | Operating V_{BS} Supply Current for each Channel | $f_{HIN1,2,3}=20\text{kHz}$, rms Value | | 400 | 800 | μA |
| V_{BSUV+} | V_{BS} Supply Under-Voltage Positive-going Threshold | $V_{DD}=15\text{V}$, $V_{BS}=\text{Sweep}$ | 7.2 | 8.2 | 9.0 | V |
| V_{BSUV-} | V_{BS} Supply Under-Voltage Negative-going Threshold | $V_{DD}=15\text{V}$, $V_{BS}=\text{Sweep}$ | 6.8 | 7.8 | 8.5 | V |
| V_{BSHYS} | V_{BS} Supply Under-Voltage Lockout Hysteresis | $V_{DD}=15\text{V}$, $V_{BS}=\text{Sweep}$ | | 0.4 | | V |
| I_{LK} | Offset Supply Leakage Current | $V_{B1,2,3}=V_{S1,2,3}=600\text{V}$ | | | 10 | μA |
| GATE DRIVER OUTPUT SECTION | | | | | | |
| V_{OH} | High-level Output Voltage, $V_{BIAS}-V_O$ | $I_O=20\text{mA}$ | | | 1.0 | V |
| V_{OL} | Low-level Output Voltage, V_O | $I_O=20\text{mA}$ | | | 0.6 | V |
| $I_{O+}^{(4)}$ | Output HIGH Short-circuit Pulsed Current | $V_O=0\text{V}$, $V_{IN}=5\text{V}$ with $PW<10\mu\text{s}$ | 250 | 350 | | mA |
| $I_{O-}^{(4)}$ | Output LOW Short-circuit Pulsed Current | $V_O=15\text{V}$, $V_{IN}=0\text{V}$ with $PW<10\mu\text{s}$ | 500 | 650 | | mA |
| V_S | Allowable Negative V_S Pin Voltage for IN Signal Propagation to H_O | | | -9.8 | -7.0 | V |
| LOGIC INPUT SECTION (HIN, LIN) | | | | | | |
| V_{IH} | Logic "1" Input Voltage | | 2.5 | | | V |
| V_{IL} | Logic "0" Input Voltage | | | | 1.0 | V |
| I_{IN+} | Logic "1" Input Bias Current | $V_{IN}=5\text{V}$ | | 25 | 50 | μA |
| I_{IN-} | Logic "0" Input Bias Current ⁽⁴⁾ | $V_{IN}=0\text{V}$ | | | 2.0 | μA |
| R_{IN} | Input Pull-down Resistance | | 100 | 200 | 300 | $\text{K}\Omega$ |

Note:

4. This parameter is guaranteed by design.

Dynamic Electrical Characteristics

$T_A=25^\circ\text{C}$, $V_{\text{BIAS}} (V_{\text{DD}}, V_{\text{BS1,2,3}})=15.0\text{V}$, $V_{\text{S1,2,3}}=\text{GND}$, $C_{\text{Load}}=1000\text{pF}$ unless otherwise specified.

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|------------------|--|-------------------------------|------|------|------|------|
| t_{ON} | Turn-on Propagation Delay | $V_{\text{S1,2,3}}=0\text{V}$ | | 130 | 220 | ns |
| t_{OFF} | Turn-off Propagation Delay | $V_{\text{S1,2,3}}=0\text{V}$ | | 150 | 240 | ns |
| t_{R} | Turn-on Rise Time | | | 50 | 120 | ns |
| t_{F} | Turn-off Fall Time | | | 30 | 80 | ns |
| MT1 | Turn-on Delay Matching $t_{\text{ON(H)}} - t_{\text{OFF(L)}} $ | | | | 50 | ns |
| MT2 | Turn-off Delay Matching $t_{\text{OFF(H)}} - t_{\text{ON(L)}} $ | | | | 50 | ns |
| DT | Dead Time | | 100 | 270 | 440 | ns |
| MDT | Dead-time Matching $t_{\text{DT1}} - t_{\text{DT2}} $ | | | | 60 | ns |

Typical Characteristics

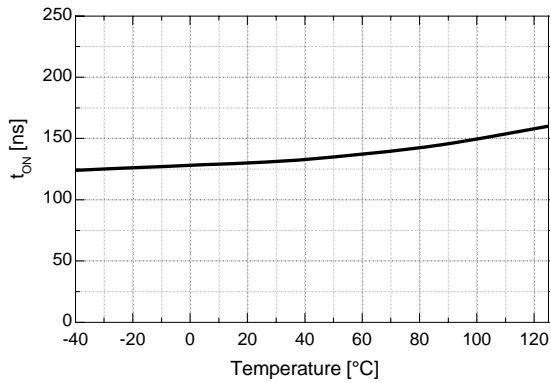


Figure 4. Turn-on Propagation Delay vs. Temp.

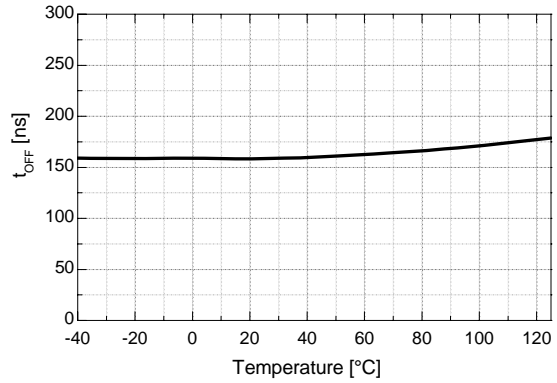


Figure 5. Turn-off Propagation Delay vs. Temp.

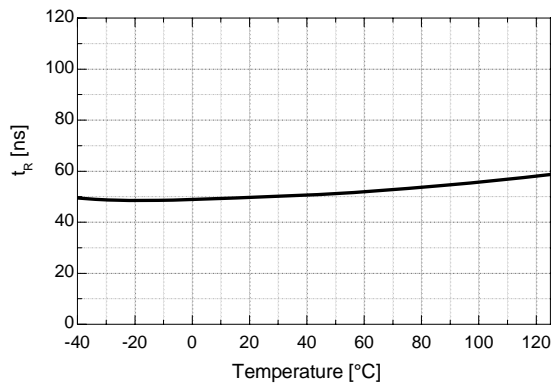


Figure 6. Turn-on Rise Time vs. Temp.

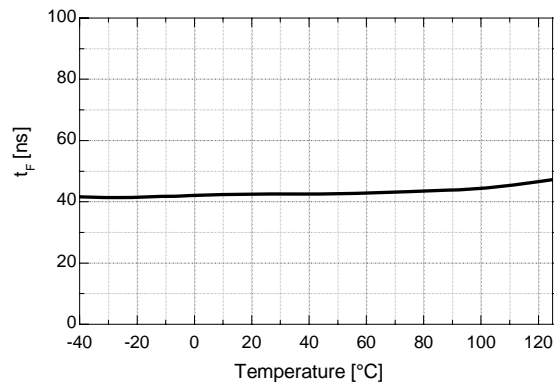


Figure 7. Turn-off Fall Time vs. Temp.

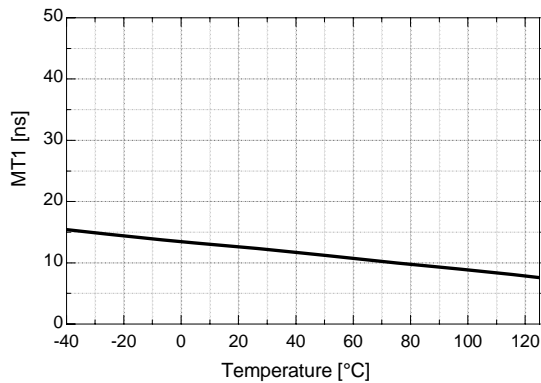


Figure 8. Turn-on Delay Matching vs. Temp.

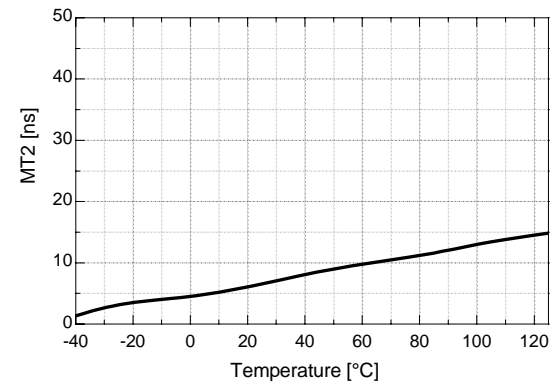


Figure 9. Turn-off Delay Matching vs. Temp.

Typical Characteristics (Continued)

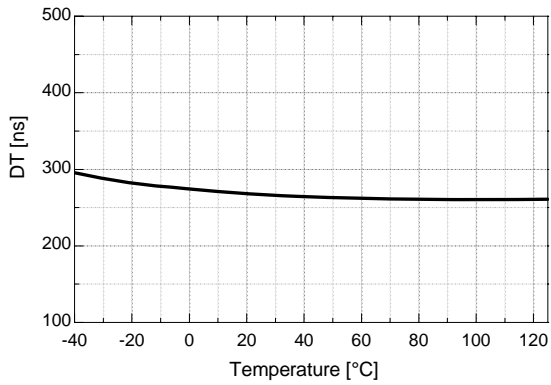


Figure 10. Dead Time vs. Temp.

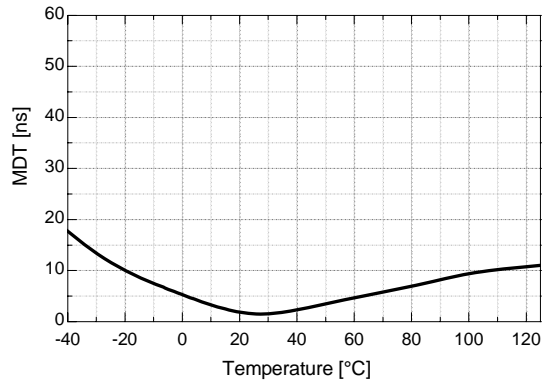


Figure 11. Dead-Time Matching vs. Temp.

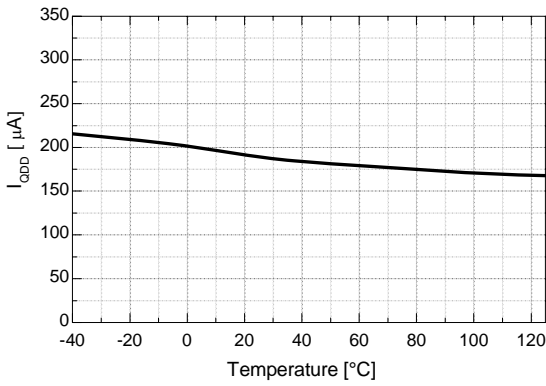


Figure 12. Quiescent V_{DD} Supply Current vs. Temp.

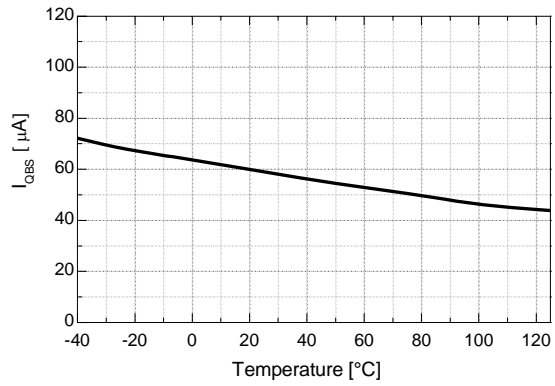


Figure 13. Quiescent V_{BS} Supply Current vs. Temp.

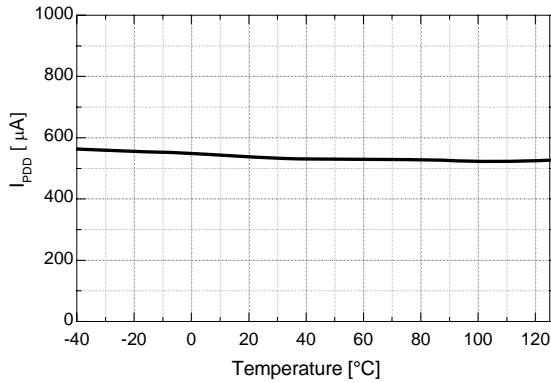


Figure 14. Operating V_{DD} Supply Current vs. Temp.

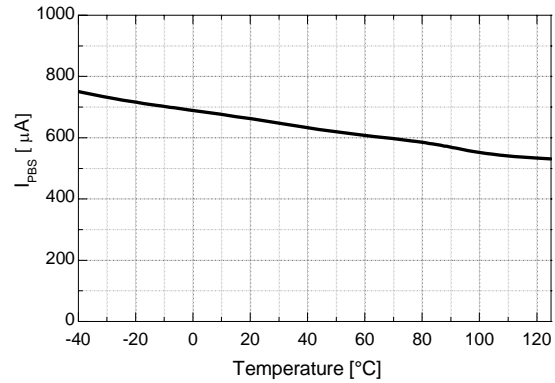


Figure 15. Operating V_{BS} Supply Current vs. Temp.

Typical Characteristics (Continued)

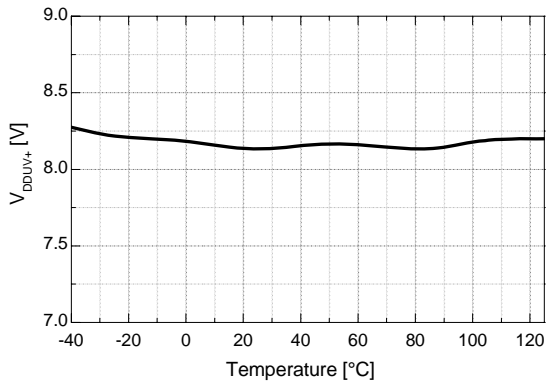


Figure 16. V_{DD} UVLO+ vs. Temp.

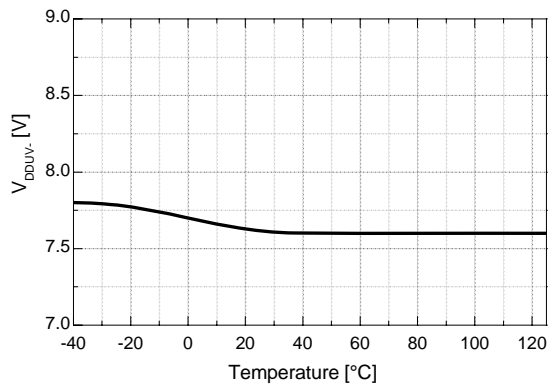


Figure 17. V_{DD} UVLO- vs. Temp.

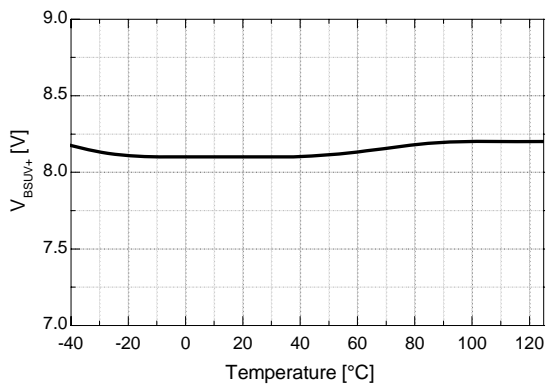


Figure 18. V_{BS} UVLO+ vs. Temp.

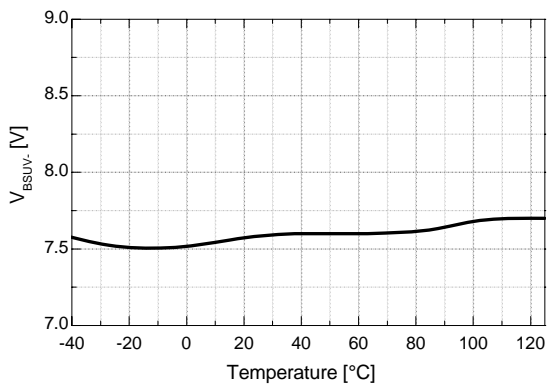


Figure 19. V_{BS} UVLO- vs. Temp.

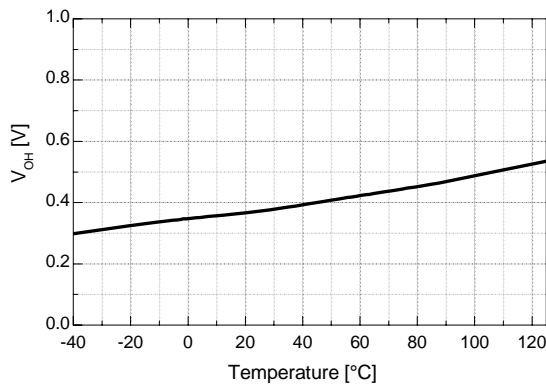


Figure 20. High-Level Output Voltage vs. Temp.

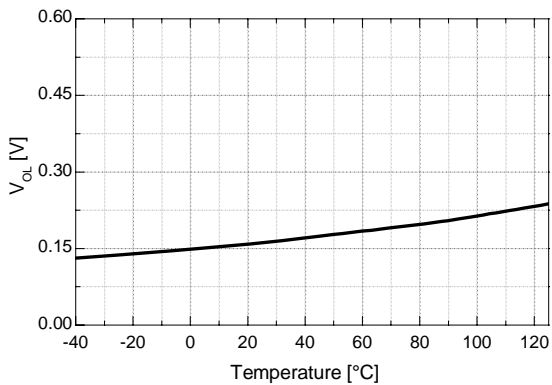


Figure 21. Low-Level Output Voltage vs. Temp.

Typical Characteristics (Continued)

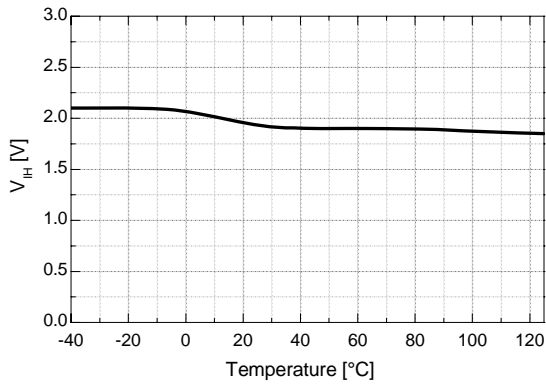


Figure 22. Logic High Input Voltage vs. Temp.

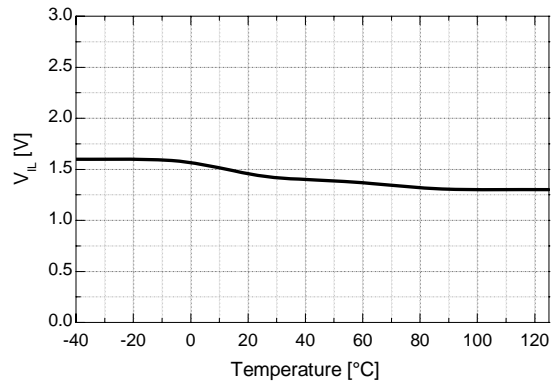


Figure 23. Logic Low Input Voltage vs. Temp.

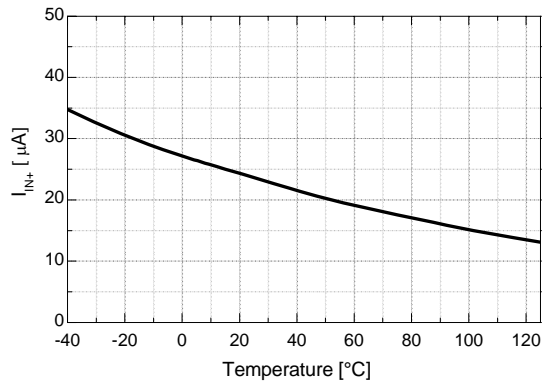


Figure 24. Logic Input High Bias Current vs. Temp.

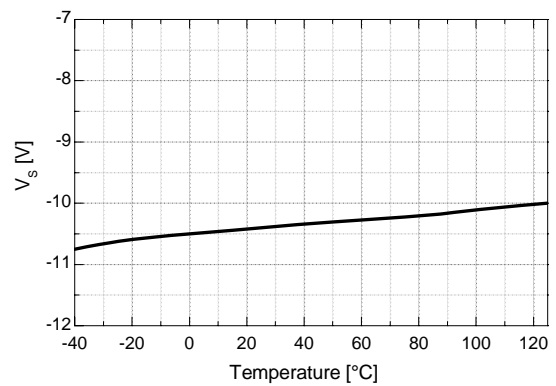


Figure 25. Allowable Negative V_S Voltage vs. Temp.

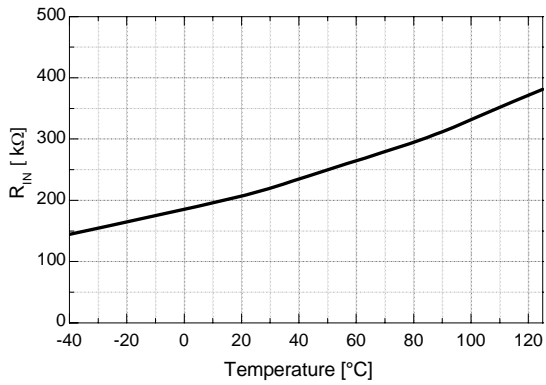


Figure 26. Input Pull-down Resistance vs. Temp.

Application Information

1. Protection Function

1.1 Under-Voltage Lockout (UVLO)

The high- and low-side drivers include under-voltage lockout (UVLO) protection circuitry for each channel that monitors the supply voltage (V_{DD}) and bootstrap capacitor voltage ($V_{BS1,2,3}$) independently. It can be designed to prevent malfunction when V_{DD} and $V_{BS1,2,3}$ are lower than the specified threshold voltage. The UVLO hysteresis prevents chattering during power supply transitions.

1.2 Shoot-Through Prevention Function

The FAN7388 has shoot-through prevention circuitry monitoring the high- and low-side control inputs. It can be designed to prevent outputs of high and low side from turning on at same time, as shown Figure 27 and 28.

2. Operational Notes

The FAN7388 is a three half-bridge gate driver with internal, typical 120ns dead-time for the three-phase brushless DC (BLDC) motor drive system, as shown in Figure 1.

Figure 29 shows a switching sequence of 120° electrical commutation for a three-phase BLDC motor drive system. The waveforms are idealized: they assumed that the generated back EMF waveforms are trapezoidal with flat tops of sufficient width to produce constant torque when the line currents are perfectly rectangular, 120° electrical degrees, with the switching sequence as shown in Figure 29. The operating waveforms of the wye-connection reveal that repeat every 60 electrical degrees, with each 60° segment being “commutated” to another phase, as shown in Figure 29.

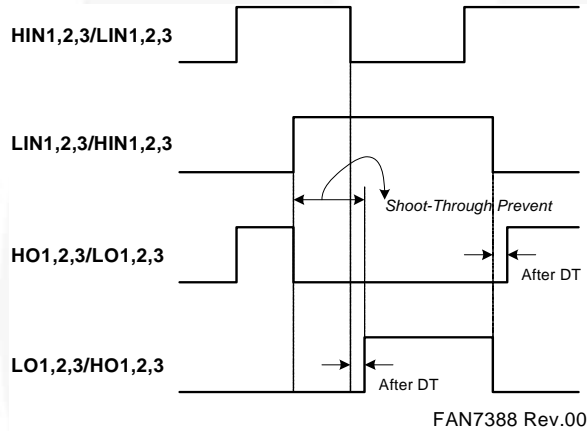


Figure 27. Waveforms for Shoot-Through Prevention

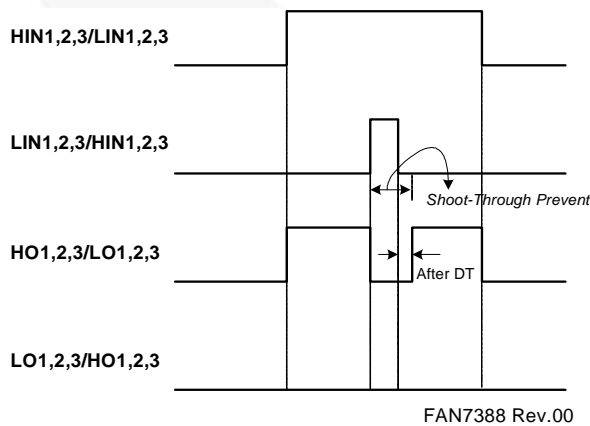


Figure 28. Waveforms for Shoot-Through Prevention

Application Information (Continued)

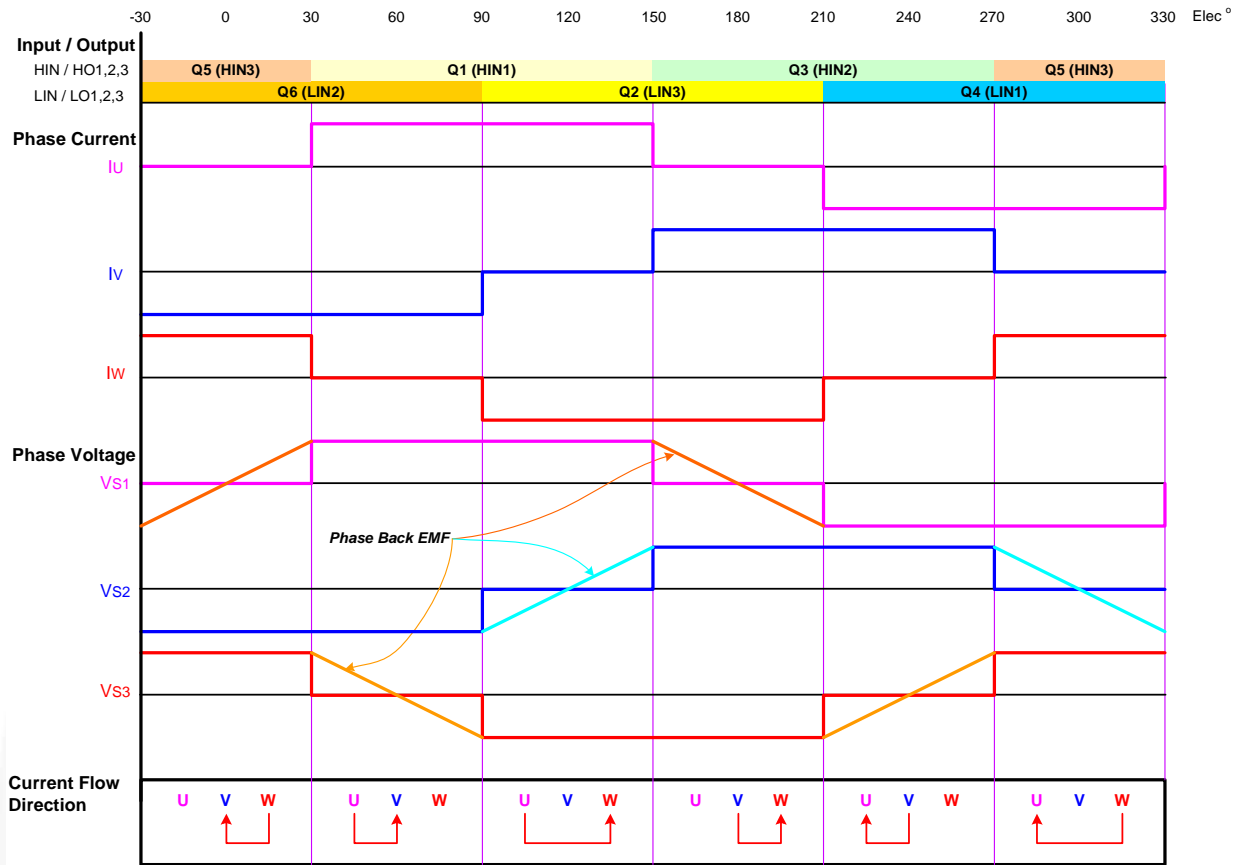


Figure 29. 120° Commutation Operation Waveforms for 3-Phase BLDC Motor Application

Switching Time Diagram

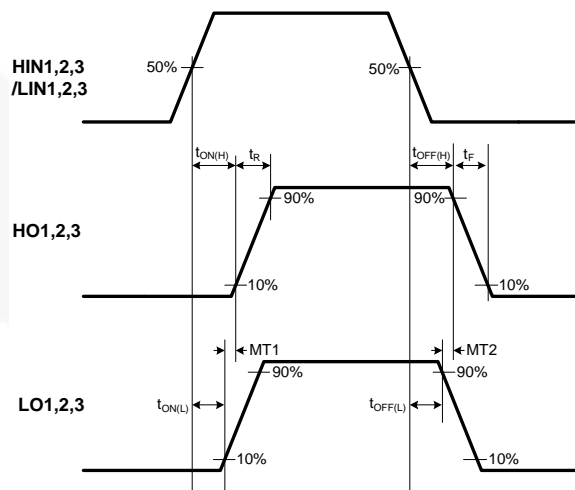
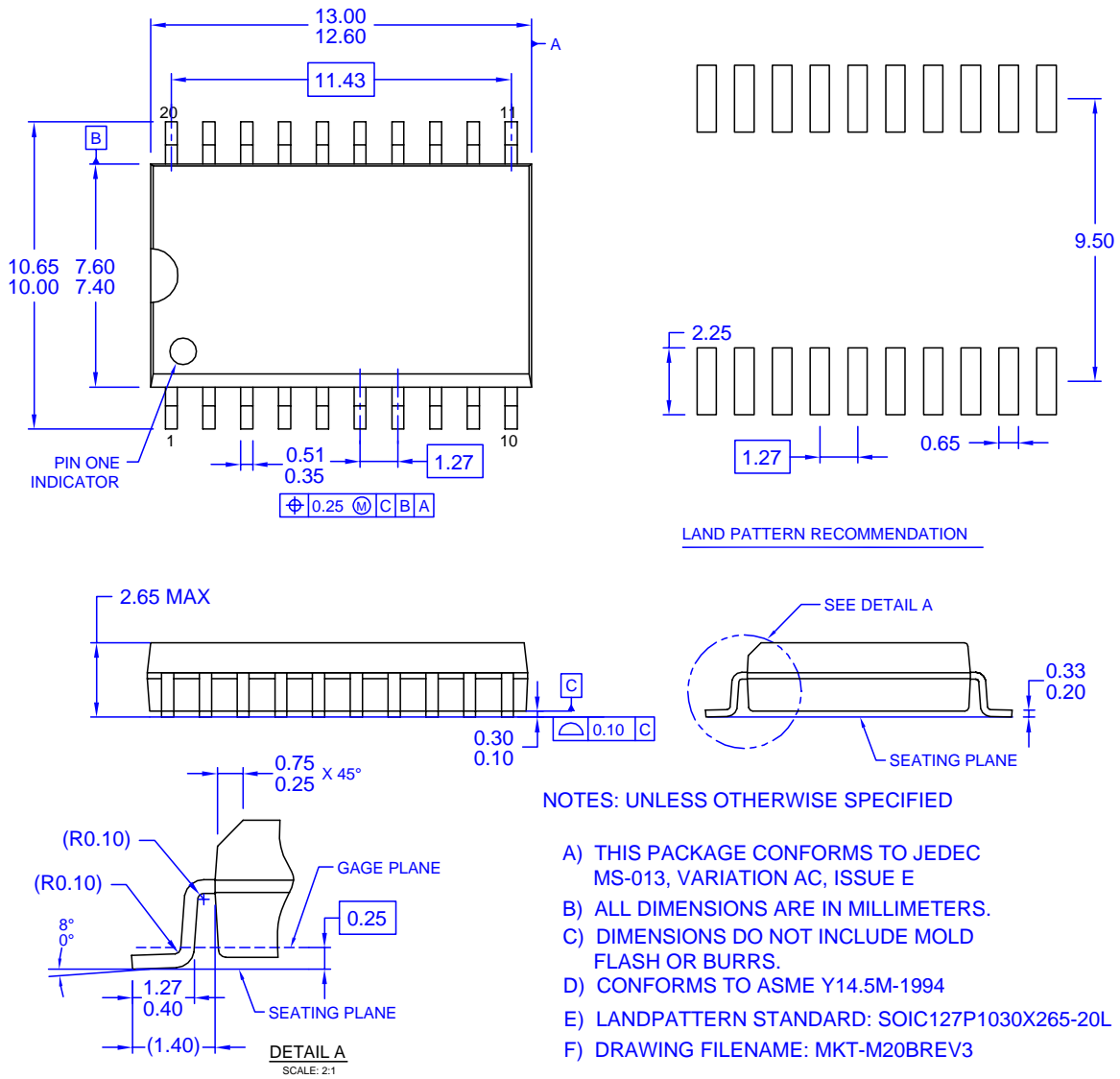


Figure 30. Switching Time Definition

Mechanical Dimensions



MKT-M20BREV3

Figure 31. 20-Lead Small Outline Package (SOIC)

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| Fairchild Semiconductor [®] | MillerDrive [™] | SuperSOT [™] -3 | Ultra FRFET [™] |
| FACT Quiet Series [™] | MotionMax [™] | SuperSOT [™] -6 | UniFET [™] |
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As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury of the user.
2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

PRODUCT STATUS DEFINITIONS

Definition of Terms

| Datasheet Identification | Product Status | Definition |
|--------------------------|-----------------------|--|
| Advance Information | Formative / In Design | This datasheet contains the design specifications for product development. Specifications may change in any manner without notice. |
| Preliminary | First Production | This datasheet contains preliminary data; supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design. |
| No Identification Needed | Full Production | This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve the design. |
| Obsolete | Not In Production | This datasheet contains specifications on a product that is discontinued by Fairchild Semiconductor. The datasheet is for reference information only. |

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