AN5277

Application note

# Introduction to the new fast 650 V HB2 IGBT series on a two-switch forward welding equipment

## Introduction

The industrial equipment market is growing fast and it requires energy- and cost-saving solutions in order to meet design requirements. STMicroelectronics is constantly engaged in the pursuit of new technology solutions to meet the market request, maintaining the high standards of quality and reliability that ST has always guaranteed.

The HB2 series is the latest fast 650 V IGBT series. The advanced IGBT inverter technology is greatly used in all types of welding processes with the generation of different types of current or amperage to handle high loads of arc welding.

The introduction of these power stages has led to a significant improvement in the performance and the functionality of welding applications. Welding machines can work very efficiently at higher operating frequencies producing the power and welding current required for a variety of materials like stainless steel, carbon steel and copper. Thanks to the development of these systems, welding features such as the size, the weight reduction and the easy handling capability have been achieved with enhanced energy and process efficiency.

In particular, the use of the HB2 series in a high-frequency inverter welding unit can lead to further benefits thanks to its improved switching characteristics and without jeopardizing the performance of the conduction losses.

The purpose of this application note is to compare the new 650 V HB2 IGBT series versus the 650 V HB series by measuring their final efficiency on a 3 kW two-switch forward welding equipment. The advantage of using this new IGBT series will be widely discussed, and it will be highlighted how this new IGBT series will be absolutely pin-to-pin compatible with its previous generation.

Focusing on manual metal arc (MMA) welding machines, there are different switched power supply topologies applied to the arc welding processes; in this document we have focused on the two-switch forward configuration that offers the best characteristics for boosting efficiency in welding applications.

# 1 STMicroelectronics' welding milestones: HB and V series IGBTs

ST Microelectronics is a market leader in power solutions thanks to a wide product portfolio featuring several devices and technologies, such as high-voltage (HV) and low-voltage (LV) Power MOSFETs, bipolar junction transistors (BJTs), IGBTs and the state-of-the-art wide bandgap technologies, like the silicon carbide and the gallium nitride Power MOSFET devices.

ST's experience with IGBTs can be traced back to many years ago: planar devices were the first product released to the market, and they still represent an important portion of ST's IGBT products portfolio, targeting several applications thanks to the different $V_{CE(sat)}$ vs $E_{off}$ series. ST accepted the challenge of trench-gate IGBTs and has been able to introduce to the market solutions which today range from 600 V to 1250 V. Thanks to their appropriate design and the wide package availability, ST's IGBTs are worldwide used in any kind of power applications. With the introduction of the trench-gate technology, ST has been able to provide more efficient and reliable solutions in comparison with planar devices thanks to better $V_{CE(sat)}$, $E_{off}$, thermal resistance and wider SOA.

The 650 V HB series and the 600 V V series, as well as the 1200 V H series, represent the fast trench-gate field-stop IGBT series currently present in the product portfolio. In detail,the HB series is the first one featuring 1.6 V of typical $V_{CE(sat)}$ @ $I_{CN}$ and a very good $E_{off}$ as well, together with a turn-off waveform showing very limited overshoot at low $R_G$ values (and very good EMC behavior); the V series features 1.85 V of $V_{CE(sat)}$ @ $I_{CN}$ and outstanding $E_{off}$ values, showing the so-called tail-less switching-off. These two series, thanks to the different conduction/switching trade-off, cover a very wide switching range (from 16 to 60 kHz for the HB series and from 50 to 100 kHz for the V series), and the several current capabilities are available in discrete packages (from 20 A to 80 A) always guarantee a very high efficiency level. These two IGBT series have contributed in a significant growth of ST's market share, not only in the welding market, but also in solar and UPS equipment. Moreover, enhanced switching performance IGBTs are gaining a great interest in an application which is typically driven by MOSFETs, that is the PFC: high current capability can be reached in a considerably smaller die size comparing to a super-junction MOSFET, thus many manufacturers are now widely adopting IGBT solutions for this kind of application as well.

# 2 Introduction to the new HB2 series

Considering that the market requests for devices to be more and more efficient, the power semiconductor manufacturers are always in search for new solutions to keep up with this trend and guarantee the best switching performance. The HB2 series represents the evolution of the former HB series, both in terms of current density and of switching performances, maintaining the milestone achieved by the HB series and enhancing the application performance as it will be shown in detail in the present document.

First of all, the typical $V_{CE(sat)}$ value has been reduced from 1.6 V to 1.55 V. This data may not appear as a great improvement, but the $V_{CE(sat)}$ comparison below shows that the $V_{CE(sat)}$ curve in an HB2 40 A IGBT device offers important benefits in terms of efficiency at light load.

**Figure 1.** $V_{CE(sat)}$ **comparison at 25 °C**

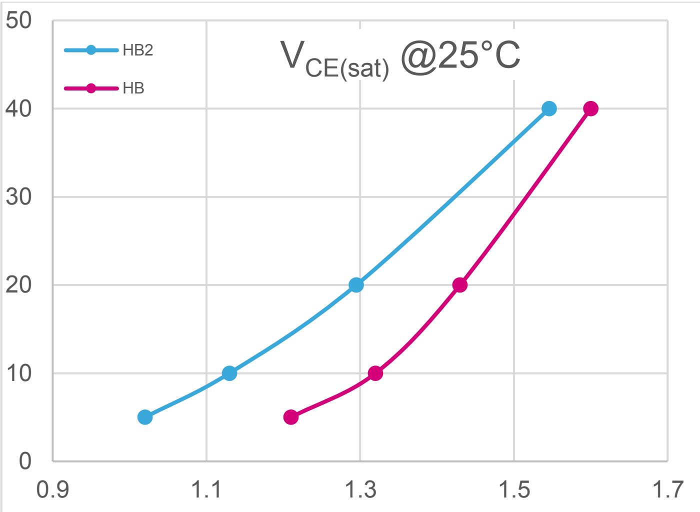
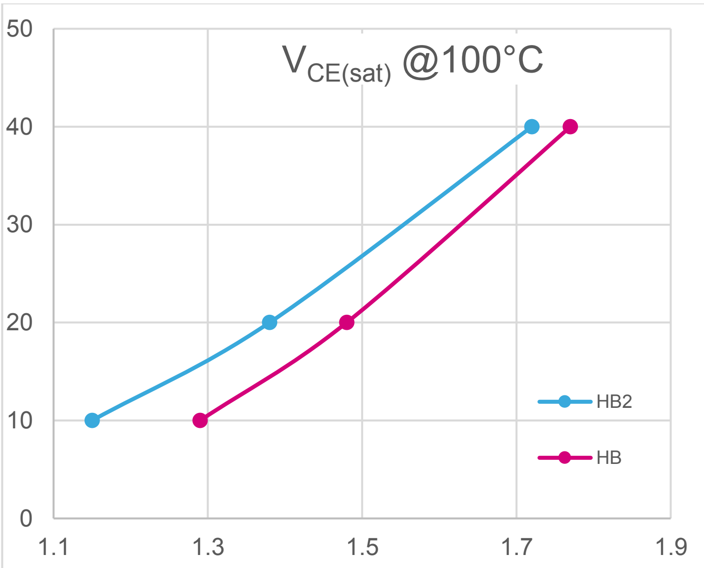
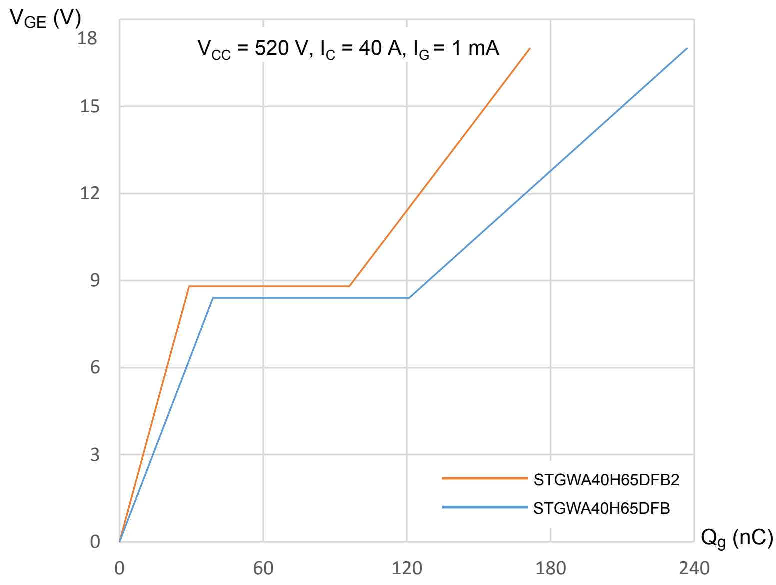



**Figure 2.** $V_{CE(sat)}$ **comparison at 100 °C**



Regarding the switching performance, it is important to underline that with the new HB2 series, comparing with the HB series, ST designers have been able to reduce the gate charge value by 25% (210 nC vs 153 nC). This data, combined with the low gate resistance value that this IGBT requires, allows the system designers to use a lower current capability gate driver for proper driving the new IGBT and reaching the high-frequency capability of this device.

**Figure 3. Gate charge comparison**



# 3 Two-switch forward distinctive features

In MMA welding processes, the electrical parameters of the arc are characterized by high currents and low voltage drop. Typically, the current range varies from 50 to 100 A for small machines, increasing up to several hundreds of amperes in larger ones. The arc voltage is in the order of several tens of volts and it depends on the welding process; the output characteristics of a suitable MMA power supply show that a high DC open-load voltage is present on the welding torch in the open-circuit condition. As soon as the current drained by the welding pool increases, the voltage decreases.

The power stage has to follow these requirements:

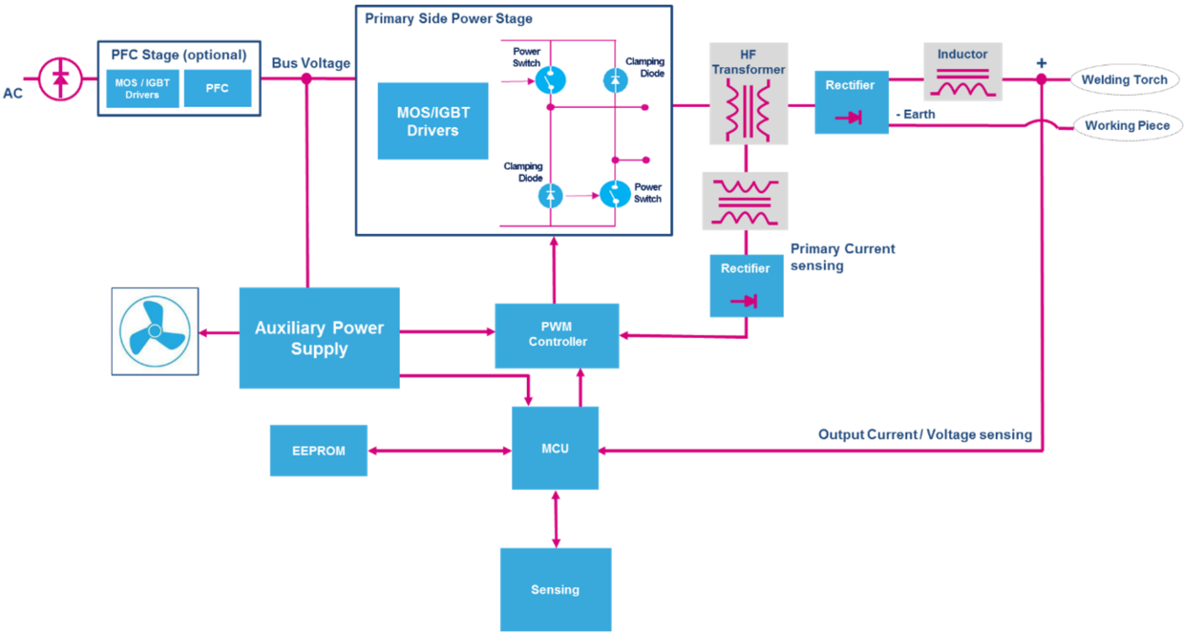
- Galvanic isolation between the main net and the output ground, in order to prevent potential damages or risks for the user since during the welding process the negative output is directly connected to the iron piece being welded;
- High-filtered DC current with low voltage drop;
- Open circuit voltage (potential difference between terminals) up to 100 V, in order to maintain the proper arc voltage;
- High frequency in order to reduce the passive component size, like the main transformer;
- High conversion efficiency.

In the present document, the reference topology used to generate low voltage and high current with low ripple is the two-switch forward converter, which offers a lot of benefits especially in high-frequency and high-voltage applications, and is widely diffused in commercial welding machines with low/medium power range applications.

This topology offers the following advantages:

- The voltage transistor stress is effectively clamped to the $V_{BUS}$, reducing any risk of potential uncontrolled voltage overshoots and allowing to select switches with a rated breakdown which is slightly higher than the maximum DC input voltage range. The leakage inductance energy is also clamped and recycled back to the input through the freewheeling diodes in order to improve efficiency.
- The topology does not require additional tertiary or core reset winding or secondary-side centre-tapped winding, thus contributing in the power transformer simplification and in cost reduction.
- System losses and noise are reduced, thanks to the effective clamping action on the voltage oscillations which are normally associated with inductive energy deliverance.
- No dissipative snubber circuit is needed since the switches are capable of working in hard-switching conditions, less components to be handled.
- Multiple isolated outputs with differentiated power or voltage ratings can be handled.

Figure 4. **Typical welding machine block diagram**




The two-switch forward converter uses two transistors which work simultaneously and are driven by a square wave with a variable duty cycle which is obtained with the PWM technique. When the transistors turn on, they transfer energy through the transformer from the primary into the secondary winding. On the secondary side, the transformer output voltage is initially scaled, then rectified by the diode bridge rectifier (half-bridge or full-bridge depending on the application requirements) and is finally filtered to provide smooth DC voltage or current.

As the transistors turn off, two freewheeling diodes discharge the leakage and magnetization inductances of the primary side winding of the transformer, and clamp the voltage on the primary winding to the ground and the $V_{BUS}$ for both the low-side and the high-side IGBTs. At that time, the power transistors need to block only the supply voltage, which means half stress compared to the single-switch solution and that no snubber circuitry is required. On the secondary side, the forward rectifying diodes start conducting, transferring the energy into the output filter and load.

The transformer core is used in the first quadrant of its B-H curve to deliver energy to the secondary side, and the duty cycle variation allows current modulation and, consequently, the welding output power modulation.

The input voltage seen by the primary switches could be the output voltage of a PFC stage which is required to maximize the real power available from the mains by regulating and stabilizing the bus voltage typically in the range of 380 V ÷ 400 V for single-phase welding machine inverters.

# 4 Electrical specifications of the tested welder

The technical data reported in the table below refers to a single-phase manual metal arc welding machine platform tested during an analysis which was performed with the 650 V HB2 series trench-gate field-stop IGBTs. The MMA-120 cheap arc welder is widely used in ferrous metal welding (such as low carbon steel, medium carbon steel and alloy steel, etc.); the advanced IGBT inverter technology was used to reach high reliability and stability, high inverter frequency, as well as energy efficiency and saving with smaller size and lighter weight.

**Table 1. Technical data of the tested welder**

| Parameter | Value |
|---|---|
| Mains voltage | 1 phase 220 V ±15% 220 V |
| Frequency | 50/60 Hz |
| Rated input power | 3.0 kW |
| Rated input current | 17 A |
| No-load voltage | 56 V |
| No-load loss | 10 W |
| Duty cycle | 26% @ 120 A |
| Output current range | 20÷120 A |
| Protection class | IP23 |
| Insulation class | H |
| Cooling | AF |
| Efficiency | ≥80% |
| Power factor | 0.8 |

Other features are the following:

- Continuous operation, stable performance/current and smooth arc to to facilitate welding.
- Automatic hot start function to boost current during starting and make arc initialization easier.
- No-load loss less than 10 W with a 50% of energy saving compared traditional welding machines.
- Overload protection with self-protective function in cases of over-voltage, low-voltage, over-current and over-heat.
- Easy to operate through a selector switch which is used to quickly adjust the welding current.

# 5 Test conditions and analysis: HB2 vs HB series IGBTs on a 3 kW welder

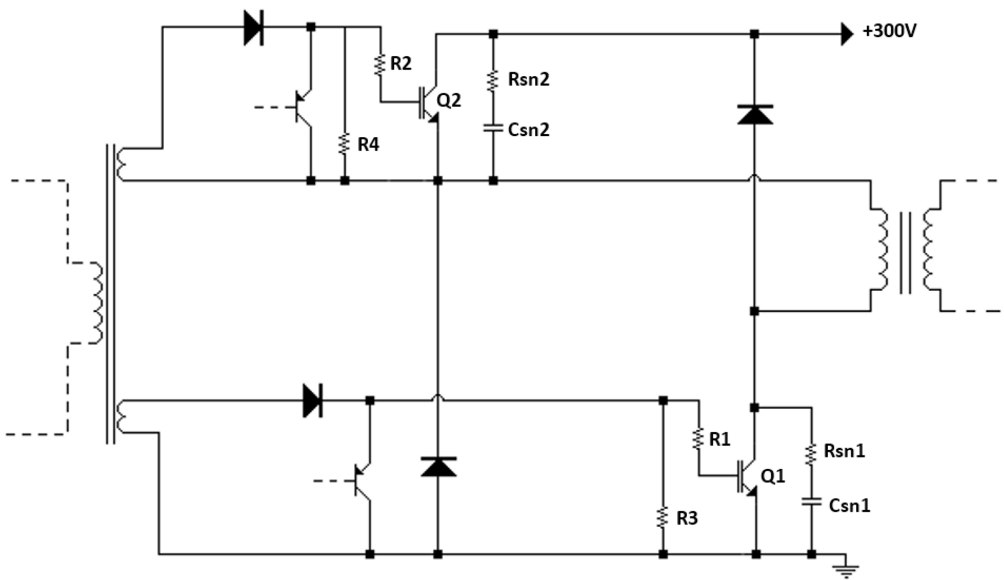
The STGWA40H65DFB2 and STGWA40H65DFB devices, both packaged in a TO-247 long leads package, have been tested and compared in a single-phase 3 kW welding machine implementing the two-switch forward converter configuration at a switching frequency of about 48 kHz. The following table lists the main parameters of these components; for more details regarding these IGBTs, please refer to the relevant datasheet available on www.st.com

**Table 2. STGWA40H65DFB2 and STGWA40H65DFB main parameters**

| Device | Package | $BV_{CES}$ | $T_{Jmax}$ | $V_{CE(sat)}$ (typ.) @25 ºC |
|---|---|---|---|---|
| STGWA40H65DFB2 | TO-247 long-leads | 650 V | 175 ºC | 1.55 V |
| STGWA40H65DFB | | 650 V | 175 ºC | 1.60 V |

Two IGBTs were connected in a double-switch forward DC-DC converter configuration of the 3 kW single-phase welding machine board which was tested in "free air" (open board without housing) conditions with an ambient temperature $T_{AMB}$ = 25 °C (+/-2 °C). Figure 5. Two-switch forward topology in welder's power converter section shows the power section of a typical double-switch forward converter where the IGBT switching devices of the same diagonal operate simultaneously.

**Figure 5. Two-switch forward topology in welder's power converter section**



The switching performance and the temperature characteristics of the IGBT devices were evaluated in full-load steady state operation under "open-board" conditions and at room temperature (25 ºC), as well as in various operating conditions for the board by stepping the input/output power level up to the maximum value, with an input main voltage of 220 VAC and a frequency of 50 Hz .

In particular, the HB2 vs HB series IGBTs were analyzed under the following test conditions:

- Switching frequency fixed to ~48 kHz
- Gate driving resistances R1, R2 = 5.6 Ω and R3, R4 = 560 Ω
- RC snubber network with Rsn1, Rsn2 = 18 Ω and Csn1, Csn2 = 1.2 nF
- Power ranging from 500 W up to maximum input power
- Output load resistance ~145 mΩ

In both the analyses, the full-load condition was reproduced by connecting the output of the board with a resistive load composed of a series of power resistances arranged in parallel and with a ceramic base in order to reach the total value of about 145 mΩ. During the tests, a fan was used to maintain a constant temperature and therefore help keeping the total resistance value to a constant level. This external fan was mounted away from the welding machine to avoid any effects on the thermal performance of the devices. Moreover, in all the tests performed, the IGBTs were screwed to the same heatsink as per the original mounting arrangement. In open-board conditions (removing the external metal cover of the welding machine) at ambient temperature (~25 °C), the measurements were performed with the IGBTs connected with wires in order to allow the insertion of the probes which were used for recording the signals. Under these conditions, particular attention was focused on the electrical behavior of parameters like the $V_{CE}$ voltage across the collector and emitter pins, the collector (or emitter) current $I_C$ and the $V_{GE}$ voltage across the gate and emitter pins during normal operation. The signal waveforms and temperatures were acquired and measured for both the low- and the high- side devices, Q1 and Q2.

# 6 Overview of thermal and electrical measurements

This section reports the results obtained from the analysis performed with the STGWA40H65DFB2 and STGWA40H65DFB IGBTs tested on a 3 kW welder. The following tables and graphics show the static electrical parameters measured using a curve tracer at 25 °C and 100 °C for both STGWA40H65DFB2 and STGWA40H65DFB IGBTs.

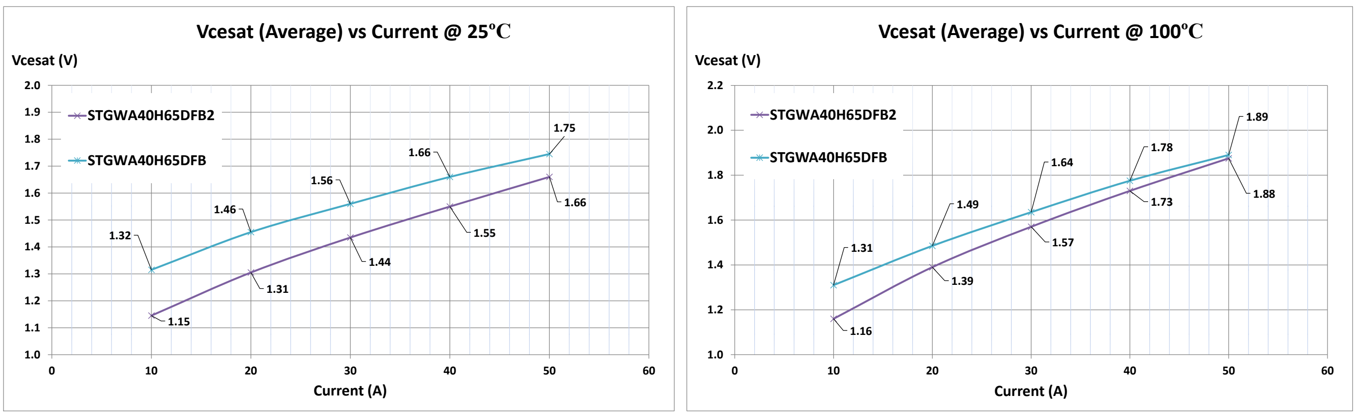
**Table 3. Static electrical parameters at 25 °C measured at curve tracer**

| $V_{CE(sat)}$ @ 25 °C [V] | | | | | | |
|---|---|---|---|---|---|---|
| Device | | Collector current [A] | | | | |
| | | 10 | 20 | 30 | 40 | 50 |
| STGWA40H65DFB2 | Q1 | 1.14 | 1.3 | 1.43 | 1.54 | 1.65 |
| | Q2 | 1.15 | 1.31 | 1.44 | 1.56 | 1.67 |
| **Average value**: | | **1.15** | **1.31** | **1.44** | **1.55** | **1.66** |
| STGWA40H65DFB | Q1 | 1.3 | 1.45 | 1.55 | 1.65 | 1.73 |
| | Q2 | 1.33 | 1.46 | 1.57 | 1.67 | 1.76 |
| **Average value**: | | **1.32** | **1.46** | **1.56** | **1.66** | **1.75** |

**Table 4. Static electrical parameters at 100 °C measured at curve tracer**

| $V_{CE(sat)}$ @ 100 °C [V] | | | | | | |
|---|---|---|---|---|---|---|
| Device | | Collector current [A] | | | | |
| | | 10 | 20 | 30 | 40 | 50 |
| STGWA40H65DFB2 | Q1 | 1.15 | 1.38 | 1.56 | 1.72 | 1.86 |
| | Q2 | 1.17 | 1.4 | 1.58 | 1.74 | 1.89 |
| **Average value**: | | **1.16** | **1.39** | **1.57** | **1.73** | **1.88** |
| STGWA40H65DFB | Q1 | 1.29 | 1.48 | 1.63 | 1.77 | 1.88 |
| | Q2 | 1.33 | 1.49 | 1.64 | 1.78 | 1.9 |
| **Average value**: | | **1.31** | **1.49** | **1.64** | **1.78** | **1.89** |

**Figure 6. $V_{CE(sat)}$ (average) vs current curves at 25 °C and 100 °C**



As it can be seen from the data above, the $V_{CE(sat)}$ voltages of the tested devices are aligned to the typical values, with the IGBT STGWA40H65DFB2 showing better $V_{CE(sat)}$ characteristics.

The following tables and figures show the electrical measurements for the input power, input current and power factor (PF) taken by the power meter at the input of the welder as well as the temperature and time values achieved by the STGWA40H65DFB2 and STGWA40H65DFB IGBTs during the electro-thermal analysis carried out on the board.

The operating conditions for the application (220 VAC, 50 Hz input) are the following:

- full-load steady state operation under 500 W input power;
- full-load steady state operation under 1 kW input power;
- full-load steady state operation under 2 kW input power;
- full-load steady state operation under 2.5kW input power;
- full-load steady state operation under maximum power absorbed in input conditions.

The case temperatures were measured using a thermal camera once the thermal stability had been achieved by the devices running on the board.

**Table 5. STGWA40H65DFB2 thermal and electrical measurements**

| Input power [W] | Duty cycle [%] | Input current [A] | Power factor | Output power [W] | System efficiency [%] | Temperature [ºC] |
|---|---|---|---|---|---|---|
| **500** | **11.3** | 3.4 | 0.65 | 400 | **80.1** | **42** |
| **1000** | **15.1** | 6.2 | 0.70 | 810 | **81.0** | **53** |
| **1500** | **18.9** | 9.0 | 0.73 | 1229 | **81.9** | **65** |
| **2000** | **20.8** | 11.8 | 0.74 | 1652 | **82.6** | **76** |
| **2500** | **22.7** | 14.4 | 0.76 | 2082 | **83.3** | **87** |
| **MAX**(1) | **25.5** | 16.9 | 0.77 | 2500 | **83.9** | **98** |

1. *Maximum power is around 2978 W.*

**Table 6. STGWA40H65DFB thermal and electrical measurements**

| Input power [W] | Duty cycle [%] | Input current [A] | Power factor | Output power [W] | System efficiency [%] | Temperature [ºC] |
|---|---|---|---|---|---|---|
| **500** | **11.3** | 3.5 | 0.62 | 398 | **79.6** | **47** |
| **1000** | **15.1** | 6.4 | 0.68 | 806 | **80.6** | **59** |
| **1500** | **18.9** | 9.1 | 0.72 | 1223 | **81.5** | **70** |
| **2000** | **20.8** | 11.9 | 0.74 | 1644 | **82.2** | **81** |
| **2500** | **22.7** | 14.5 | 0.76 | 2070 | **82.8** | **92** |
| **MAX**(1) | **25.5** | 16.9 | 0.77 | 2487 | **83.5** | **103** |

1. *Maximum power is around 2978 W.*

**Table 7.** Overview of STGWA40H65DFB2 results: power losses vs input power

| Power losses [W] | | Input power [W] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 500 | 1000 | 1500 | 2000 | 2500 | MAX(1) |
| Conduction power losses [W] | Q1 | 2.4 | 5.3 | 7.9 | 10.9 | 13.6 | 17.5 |
| | Q2 | 2.4 | 5.3 | 8.1 | 11.1 | 13.9 | 17.9 |
| Switching power losses [W](2) | Q1 | 7.9 | 13.1 | 17.5 | 21.8 | 26.2 | 29 |
| | Q2 | 12.1 | 18 | 21.8 | 25.5 | 28.7 | 30.9 |
| Single switch total power losses [W] | Q1 | 10.3 | 18.4 | 25.4 | 32.7 | 39.8 | 46.5 |
| | Q2 | 14.5 | 23.3 | 29.9 | 36.6 | 42.6 | 48.8 |
| **Q1+Q2 total power losses [W]** | | **24.8** | **41.7** | **55.3** | **69.3** | **82.4** | **95.3** |

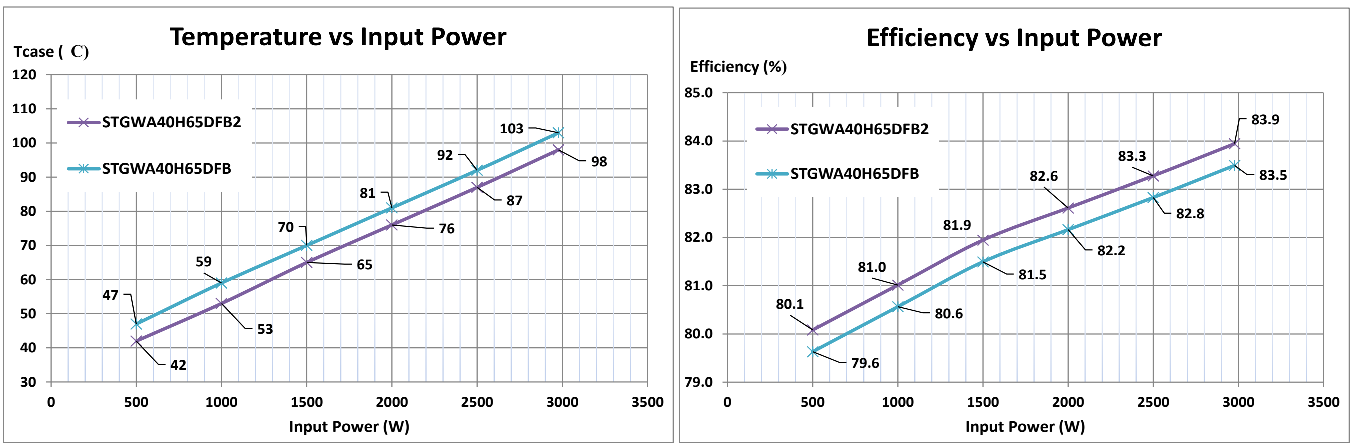
1. *Maximum power is around 2978 W.*
2. *Turn-on switching losses are negligible.*

**Table 8.** Overview of STGWA40H65DFB results: power losses vs input power

| Power losses [W] | | Input power [W] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 500 | 1000 | 1500 | 2000 | 2500 | MAX(1) |
| Conduction power losses [W] | Q1 | 2.7 | 5.7 | 8.4 | 11.2 | 13.8 | 17.4 |
| | Q2 | 2.7 | 5.7 | 8.5 | 11.4 | 14.1 | 17.7 |
| Switching power losses [W](2) | Q1 | 10.7 | 17.2 | 22.0 | 25.5 | 29.0 | 32.2 |
| | Q2 | 15.0 | 22.2 | 26.6 | 29.1 | 32.0 | 34.6 |
| Single switch total power losses [W] | Q1 | 13.4 | 22.9 | 30.4 | 36.7 | 42.8 | 49.6 |
| | Q2 | 17.7 | 27.9 | 35.1 | 40.5 | 46.1 | 52.3 |
| **Q1+Q2 total power losses [W]** | | **31.1** | **50.8** | **65.5** | **77.2** | **88.9** | **101.9** |

1. *Maximum power is around 2978 W.*
2. *Turn-on switching losses are negligible.*

**Figure 7.** Temperature and efficiency vs input power




As evidenced from the above data, the STGWA40H65DFB2 IGBT device achieves lower measured temperatures and higher efficiency levels from 0.5 kW to 3 kW welding input power rating.

Table 9. **Results overview: conduction power losses vs input power**

| Device | | Conduction losses [W] vs input power [W] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 500 | 1000 | 1500 | 2000 | 2500 | MAX[(1)] |
| STGWA40H65DFB2 | Q1 | 2.4 | 5.3 | 7.9 | 10.9 | 13.6 | 17.5 |
| | Q2 | 2.4 | 5.3 | 8.1 | 11.1 | 13.9 | 17.9 |
| | Q1+Q2 | **4.8** | **10.6** | **16.0** | **22.0** | **27.5** | **35.4** |
| STGWA40H65DFB | Q1 | 2.7 | 5.7 | 8.4 | 11.2 | 13.8 | 17.4 |
| | Q2 | 2.7 | 5.7 | 8.5 | 11.4 | 14.1 | 17.7 |
| | Q1+Q2 | **5.4** | **11.4** | **16.9** | **22.6** | **27.9** | **35.1** |

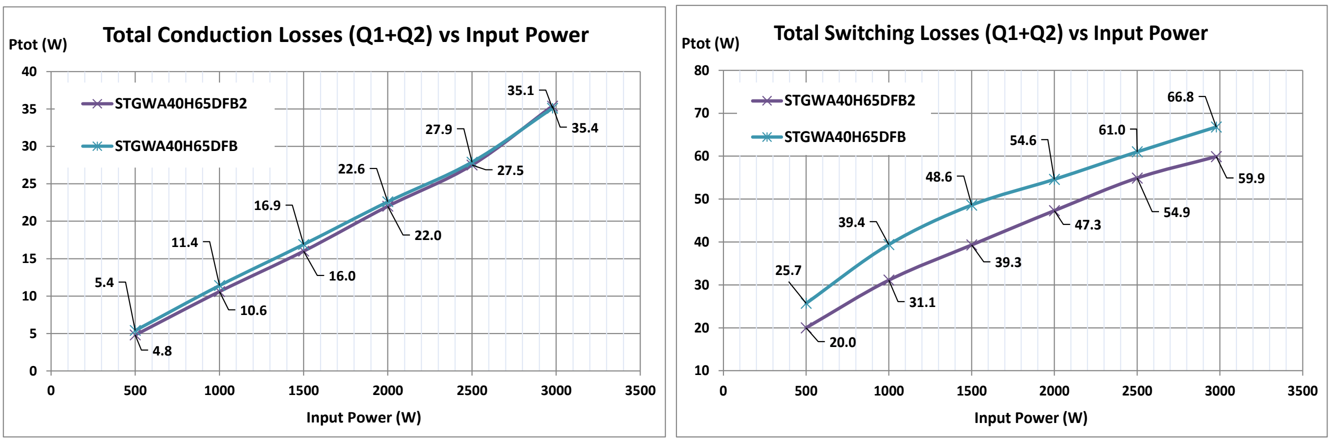
1. *Maximum power is around 2978 W.*

Table 10. **Results overview: switching power losses vs input power**

| Device | | Switching losses [W] vs input power [W] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 500 | 1000 | 1500 | 2000 | 2500 | MAX[(1)] |
| STGWA40H65DFB2 | Q1 | 7.9 | 13.1 | 17.5 | 21.8 | 26.2 | 29.0 |
| | Q2 | 12.1 | 18.0 | 21.8 | 25.5 | 28.7 | 30.9 |
| | Q1+Q2 | **20.0** | **31.1** | **39.3** | **47.3** | **54.9** | **59.9** |
| STGWA40H65DFB | Q1 | 10.7 | 17.2 | 22.0 | 25.5 | 29.0 | 32.2 |
| | Q2 | 15.0 | 22.2 | 26.6 | 29.1 | 32.0 | 34.6 |
| | Q1+Q2 | **25.7** | **39.4** | **48.6** | **54.6** | **61.0** | **66.8** |

1. *Maximum power is around 2978 W.*

Figure 8. **Conduction power losses and switching power losses vs input power**



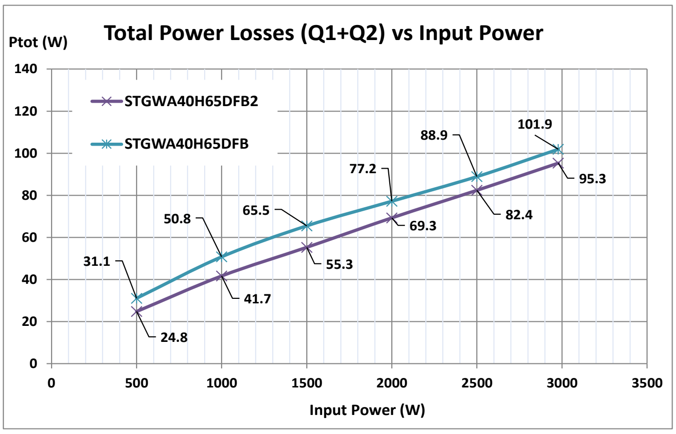

The STGWA40H65DFB2 and STGWA40H65DFB IGBTs show almost the same performance in terms of conduction losses from 0.5 kW to 3 kW welding input power variation, while the STGWA40H65DFB device has a worse performance in the whole range from 0.5 kW to 3 kW welding input power variation. The measurement of the total power losses (mathematical sum of the conduction losses and switching losses related to both low- and high-side tested IGBTs) are detailed in the table and figure below, starting from 0.5 kW up to the maximum power level.

**Table 11. Results overview: total power losses vs input power**

| Device | | Total power losses [W] vs input power [W] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 500 | 1000 | 1500 | 2000 | 2500 | MAX[1] |
| **STGWA40H65DFB2** | **Q1** | 10.3 | 18.4 | 25.4 | 32.7 | 39.8 | 46.5 |
| | **Q2** | 14.5 | 23.3 | 29.9 | 36.6 | 42.6 | 48.8 |
| | **Q1+Q2** | **24.8** | **41.7** | **55.3** | **69.3** | **82.4** | **95.3** |
| **STGWA40H65DFB** | **Q1** | 13.4 | 22.9 | 30.4 | 36.7 | 42.8 | 49.6 |
| | **Q2** | 17.7 | 27.9 | 35.1 | 40.5 | 46.1 | 52.3 |
| | **Q1+Q2** | **31.1** | **50.8** | **65.5** | **77.2** | **88.9** | **101.9** |

1. *Maximum power is around 2978 W.*

**Figure 9. Total power losses vs input power**




The STGWA40H65DFB2 IGBT device achieves lower total power losses and better functionality in comparison to the STGWA40H65DFB IGBT in the whole operating input power range.

# 7 Electrical analysis and waveforms

The signal waveforms and temperatures have been acquired and measured for both Q1 and Q2 devices which were connected in the low- and high-side sections of the two-switch forward configuration respectively. The waveforms below highlight the switching performance of the tested IGBTs.

These color codes are used in the following figures:

- Q1 collector (or emitter) current: "IC1" signal in yellow
- Q2 collector (or emitter) current: "IC2" signal in dark blue
- Q1 collector-emitter voltage: "VCE1" signal in red
- Q2 collector-emitter voltage: "VCE2" signal in green
- Q1 Instantaneous power (VCE1 x IC1): "Power" signal in orange
- Q2 Instantaneous power (VCE2 x IC2): "Power" signal in pink.

The figures below show the signals for the STGWA40H65DFB2 and the STGWA40H65DFB IGBTs during the steady state operation under maximum power input absorption conditions on the 3 kW welder.

**Figure 10. STGWA40H65DFB2 (Q1 and Q2) at maximum power**

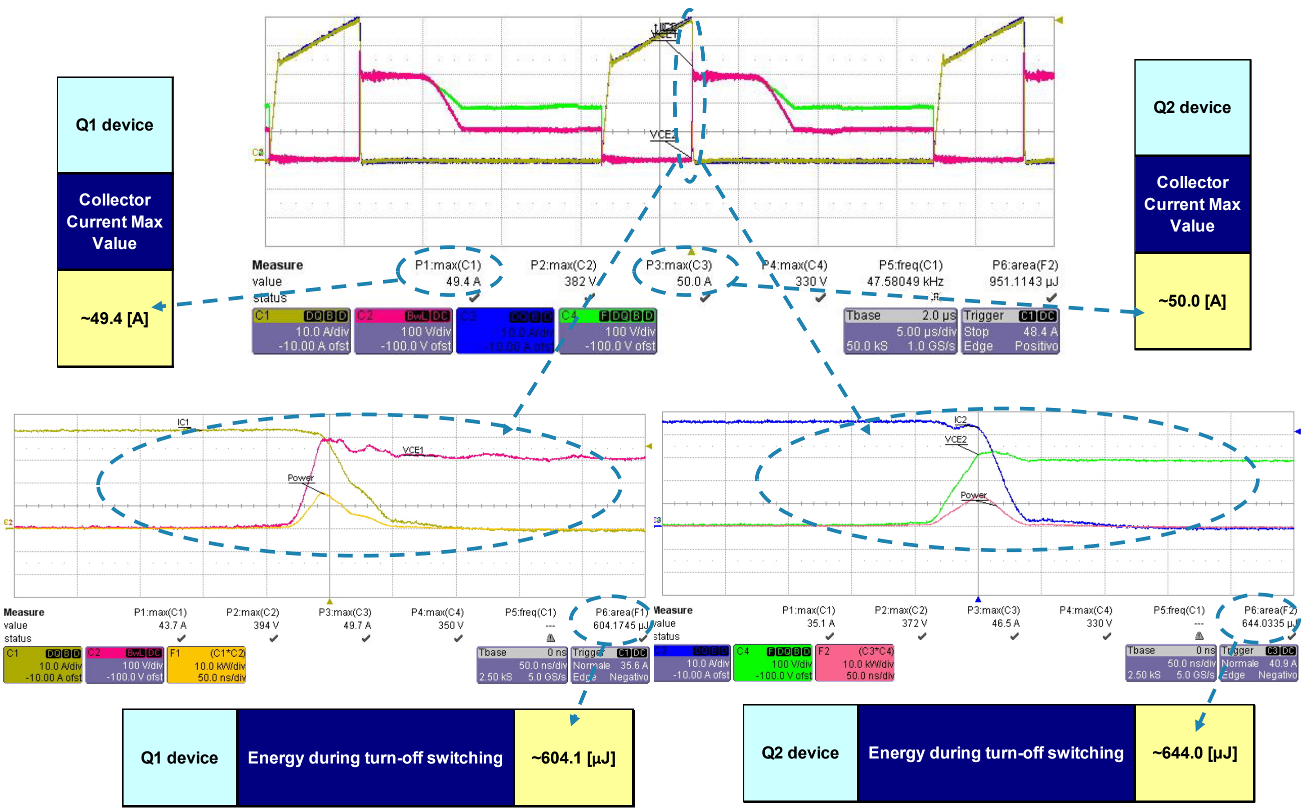
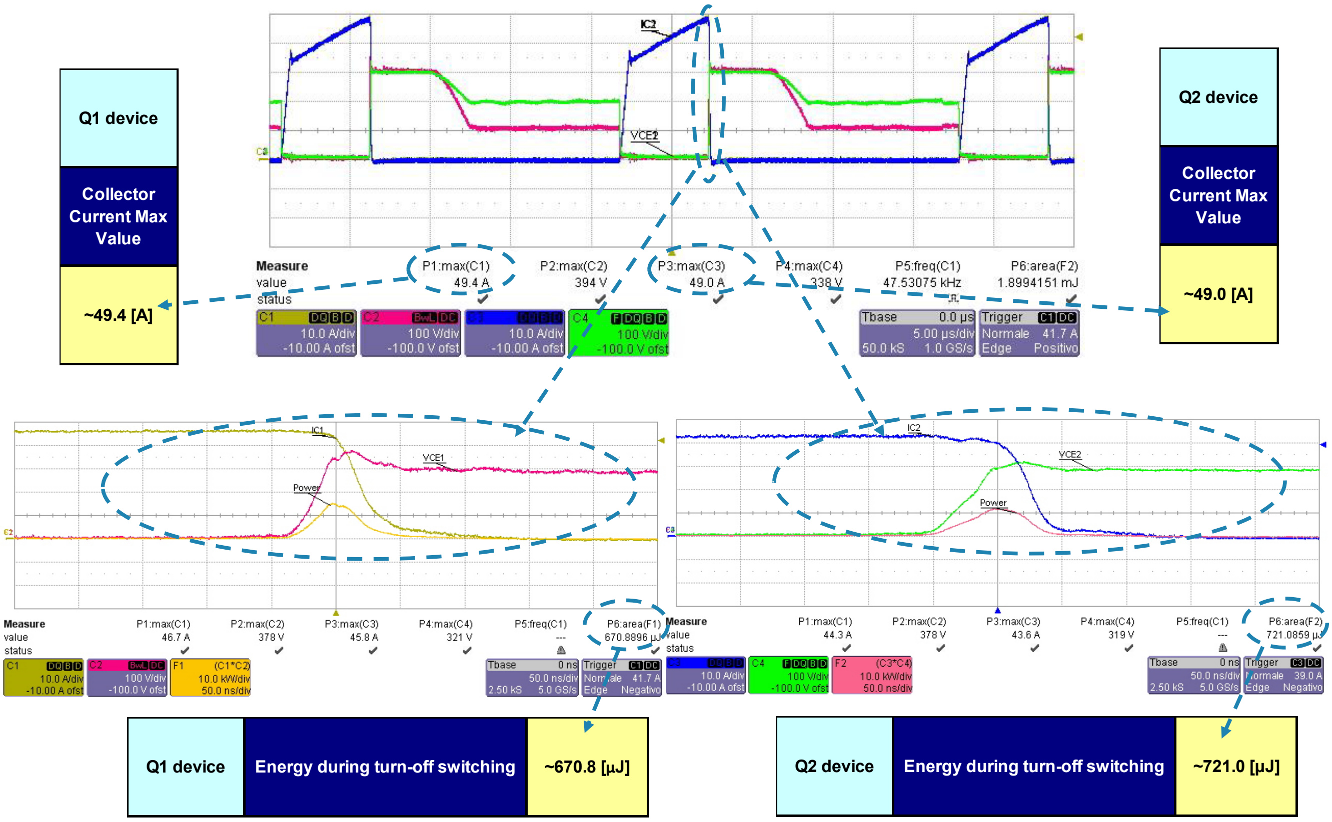


Figure 11. **STGWA40H65DFB (Q1 and Q2) at maximum power**



# 8 Conclusions

The STGWA40H65DFB2 IGBT device showed the best performance in the two-switch forward converter section of the 3 kW welding machine, achieving the lowest temperatures and power losses in pin-to-pin conditions with respect to the STGWA40H65DFB device. Therefore, the enlargement of the product portfolio is already under planning in order to cover a very wide power range also thanks to the different package solutions that STMicroelectronics has to offer. The 650 V HB2 series will surely become a benchmark in the fast IGBT market, and will be widely used in several applications like PFC, UPS, solar inverters and welding machines, consolidating the leadership of STMicroelectronics in these very important market areas.

## Revision history

Table 12. **Document revision history**

| Date | Version | Changes |
|---|---|---|
| 29-Jan-2019 | 1 | First release |

# Contents

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