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Data Sheet No. PD60358

IRMD2336DJ

3 PHASE GATE DRIVER IC REFERENCE DESIGN KIT

IRS2336DJ GATE DRIVER IC FEATURES

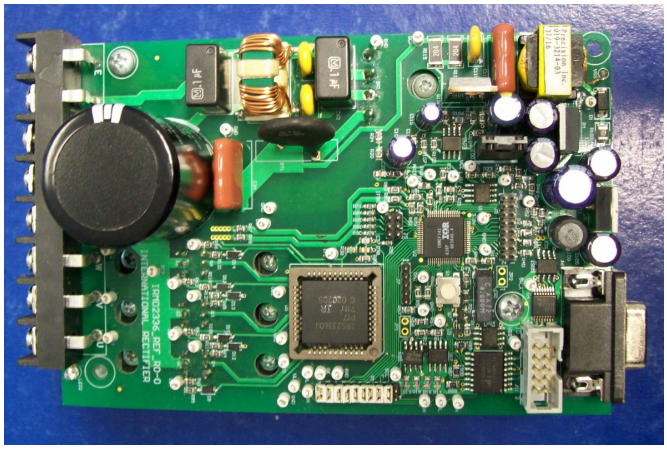
- Drives up to six IGBT/MOSFET power devices
- Gate drive supplies up to 20 V per channel
- Integrated bootstrap functionality
- Over-current protection
- Over-temperature shutdown input
- Advanced input filter
- Integrated deadtime protection
- Shoot-through (cross-conduction) protection
- Under voltage lockout for V_{CC} & V_{BS}
- Enable/disable input and fault reporting
- Adjustable fault clear timing
- Separate logic and power grounds
- 3.3 V input logic compatible
- Tolerant to negative transient voltage
- Designed for use with bootstrap power supplies
- Matched propagation delays for all channels

REFERENCE DESIGN FEATURES

- Complete 3-phase ac motor drive system to showcase IRS2336DJ gate driver IC operation
- No extra hardware needed for PWM signal generation; Option to incorporate external PWM signals to drive IRS2336DJ if desired
- GUI software for running Induction Motor in open loop Volts-per-Hertz mode of operation
- Discrete IGBT power stage for maximum flexibility
  - IGBT's rated for 10A @100°C
  - Short circuit rating 10 µs
  - TO220 Full-pak package
- Conveniently located Test points for IRS2336DJ signal monitoring

Product Summary

AC input Voltage (typ.)	220 V rms
Continuous motor current	3 A rms
dV/dt	5 kV/µs
Continuous output power	400 W



Overview

The IRMD2336DJ is a reference design kit for the IRS2336DJ three phase gate driver IC with integrated bootstrap functionality. The design kit includes a complete drive system board with an input rectifier, control power supplies, digital motor control IC and power inverter. Safety features include protections against motor line-to-line and line-to-DC Bus(-) short situations. The power stage features the IRS2336DJ gate driver and six discrete IGBT power switches allowing for easy customization. The included PC based GUI software allows the user to drive an Induction Motor in open-loop Volts-per-Hertz mode of operation using the on-board digital control IC. The motor speed and system parameters such as PWM frequency and deadtime can be modified using the GUI. Alternately, the IRS2336DJ gate drive input PWM signals can be supplied externally by patching in signals through an on-board connector.

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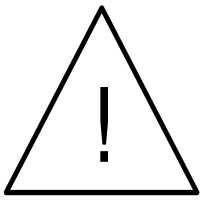
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Safety Precautions

In addition to the precautions listed throughout this manual, please read and understand the following statements regarding hazards associated with development system.



ATTENTION: The ground potential of the IRMD2336DJ system is biased to a negative DC bus voltage potential. When measuring voltage waveform by oscilloscope, the oscilloscope ground needs to be isolated. Failure to do so may result in personal injury or death.



ATTENTION: The IRMD2336DJ system contains dc bus capacitors, which take time to discharge after removal of main supply. Before working on drive system, wait three minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death.
Darkened display LEDs is not an indication that capacitors have discharged to safe voltage levels.



ATTENTION: Only personnel familiar with the drive and associated machinery should plan or implement the installation, start-up, and subsequent maintenance of the system. Failure to comply may result in personal injury and/or equipment damage.



ATTENTION: The surface temperatures of the drive may become hot, which may cause injury.

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ATTENTION: The IRMD2336DJ system contains ESD (Electrostatic Discharge) sensitive parts and assemblies. Static control precautions are required when installing, testing, servicing or repairing this assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with static control procedures, reference applicable ESD protection handbook and guideline.



ATTENTION: An incorrectly applied or installed drive can result in component damage or reduction in product life. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.



ATTENTION: Remove and lock out power from the drive before you disconnect or reconnect wires or perform service. Wait three minutes after removing power to discharge the bus voltage. Do not attempt to service the drive until bus voltage has discharged to zero. Failure to do so may result in bodily injury or death.



ATTENTION: Do not connect power factor correction capacitors to drive output terminals U, V, and W. Failure to do so may result in equipment damage or bodily injury.

Debris When Unpacking

IRMD2336DJ system is shipped with packing materials that need to be removed prior to installation.



ATTENTION: Failure to remove all debris and packing materials which are unnecessary for system installation may result in overheating or abnormal operating condition.

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IRMD2336DJ – Hardware Description

The IRMD2336DJ reference design kit supports the evaluation of the IRS2336DJ which is a high voltage power MOSFET and IGBT driver. The reference design is a full-function unit operating out of 220VAC input. An onboard digital controller IC enables driving an Induction Motor in open-loop Volts-per-Hertz mode. The included GUI software allows modification of system parameters in order to drive an induction motor in open-loop Volts-per-Hertz mode and study the IRS2336DJ high voltage gate driver IC by changing parameters such as PWM frequency and deadtime. The reference design is equipped with protection against motor line-to-line and line-to-DC Bus(-) short by way of the motor overcurrent protection function provided by IRS2336DJ and also a GUI software controlled motor current limit. The board includes multiple test points to facilitate monitoring IRS2336DJ input and output signal waveforms and examining its various features.

Top Level Description

The IRMD2336DJ reference design is composed of the following key blocks:

- The Input Stage includes an EMI filter, 8A bridge rectifier and dc bus capacitor rated for 400W continuous operation. It is noted that IRMD2336DJ does not feature a current limiting fuse.
- The Power Inverter uses 6 x IRGIB10K60D1 IGBT power switches mounted on a 1.9°C/W heatsink. The IGBTs can be replaced with user preferred power devices but user may need to replace components such as bridge rectifier & dc bus current shunt to match the device ratings.
- The Gate Driver Circuitry is based on IRS2336DJ high-voltage gate driver IC and associated circuitry involving bootstrap capacitors, gate drive timing resistors, and associated fault diagnostic elements.
- The Control Circuitry for driving the motor is based on the IRMCF341 digital control IC. The IRMCF341 control IC has been configured to run an induction motor in the open-loop Volts-per-Hertz mode. The control IC generates the PWM signals for IRS2336DJ gate driver. The user also has the option to drive the IRS2336DJ externally by disconnecting the jumpers on connector P1 and bridging in external connections. The digital IC communicates with a PC over an isolated serial link and the included GUI software allows the user to set the motor speed and modify common inverter parameters such as switching frequency and deadtime.
- An on-board DC-DC Converter low voltage power supply derives the 15V, 3.3V & 1.8V rails from the main dc bus.

For more information regarding the other blocks of the reference design, please refer to the detailed schematics.

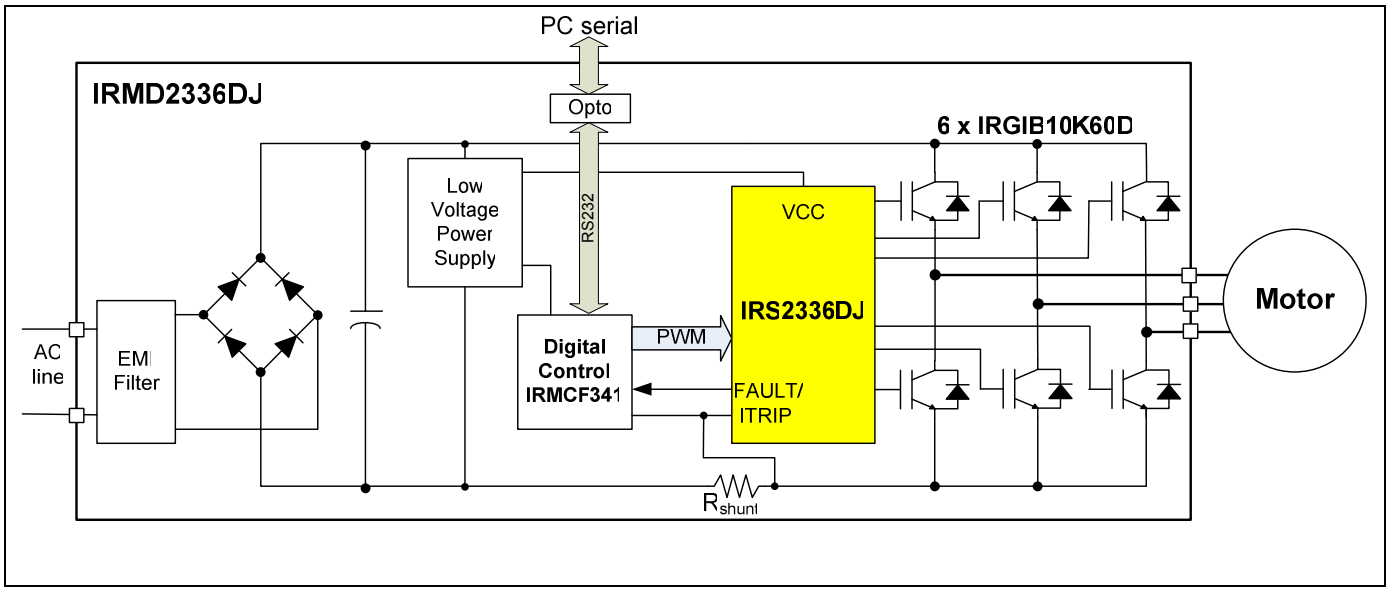


Figure 1 IRMD2336DJ System Block Diagram

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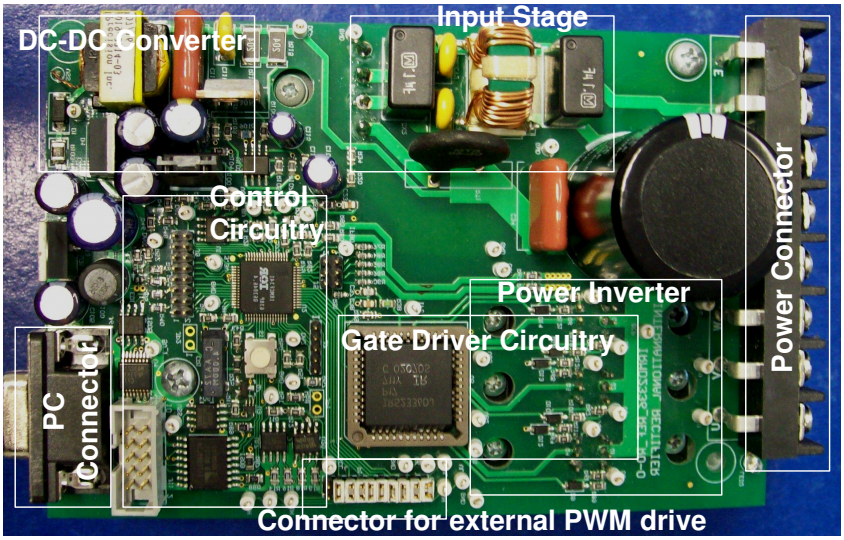


Figure 2: Picture of IRMD2336DJ Reference Design

IRS2336DJ Gate Driver IC

The IRS2336DJ IC integrates three independent half bridge drivers with shoot through protection and internal dead-time insertion. Proprietary HVIC technology enables ruggedized monolithic construction with logic inputs compatible with CMOS or LSTTL levels as low as 3.3 V. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. Propagation delays are matched to simplify use in high frequency applications. The floating channel can be used to drive N-channel power MOSFETs or IGBTs in the high side configuration, which operates up to 600V. The IC is based on “Active Low” input logic i.e. a logic HIGH input turns OFF the corresponding output and vice versa. In addition to VSS pin, the IC features a COM pin to provide a dedicated, low impedance return path for the low side gate driver which also serves to shunt the high-frequency gate drive currents away from the current sense resistor thus preventing false trips. A host of protection functions such as UVLO for VCC & VBS supplies and motor current trip along with integrated fault diagnostics are also offered in IRS2336DJ I. An open-drain $\overline{FAULT}$ signal is provided to indicate that an over-current or a VCC under-voltage shutdown has occurred. Fault conditions are cleared automatically after a delay programmed externally via an RC network connected to the RCIN input. An enable function is available to terminate all six outputs simultaneously.

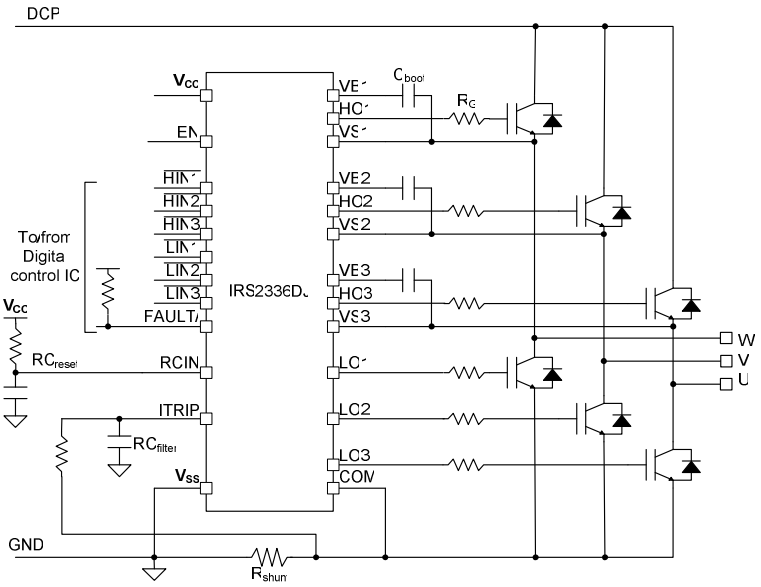


Figure 3: IRS2336DJ Application Diagram

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Bootstrap Supply Circuit

The floating high side driver supplies in IRMD2336DJ are generated by a bootstrap circuit as shown in **Figure** 4. The IC turns on the internal 'bootFET' when the low side transistor is on to charge up the bootstrap capacitor (C_{boot}). The 'bootFET' eliminates the requirement for an external bootstrap diode D_{boot} as is the case for previous generation gate drivers. An application note AN-1123 (http://www.irf.com/technical-info/appnotes/an-1123.pdf) describes the selection of the bootstrap capacitor and considerations when using the internal bootFET. In some cases, an external bootstrap circuit may be preferable. The IRMD2336DJ board also provides option for external bootstrap supply. This can be invoked by populating the bootstrap resistor, R_{boot} (R17) and bootstrap diodes (D6, D7 & D8).

The bootstrap capacitors must be fully charged to avoid missing high side pulses due to under voltage lockout on the floating high side supply. The digital controller on the board pre-charges the capacitors by turning on the low side transistors for a short period before starting to run the motor. The charging current and time depends on the resistance of the internal bootFET or the external boot resistance. Typically, the pre-charge sequence charges the capacitors one at a time to avoid spurious over current trips since the charging current flows through the current sensing shunt.

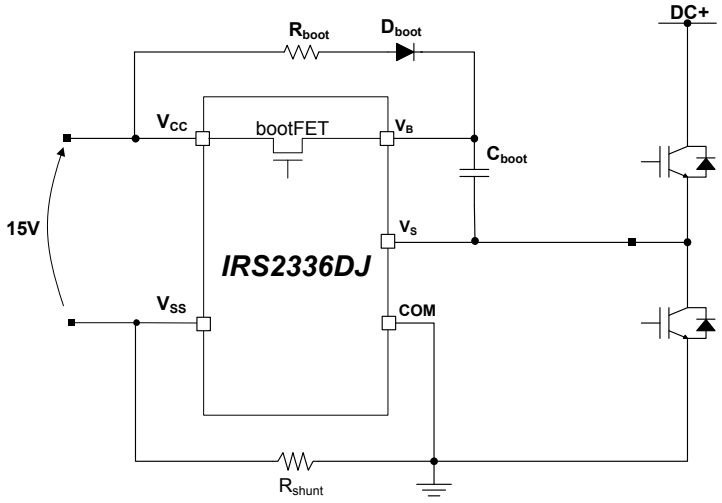


Figure 4: Bootstrap circuit

Gate Drive Resistors

The IRMD2336DJ board has resistor-diode network on the outputs of the driver IC to allow fine tuning of the power switch turn on and turn off times. **Figure 5** shows the gate circuit schematic while Table 1 lists the resistors & diodes used in the network for each power device.

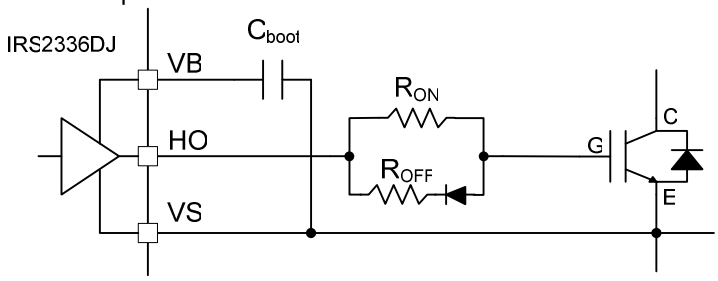


Figure 5: **Gate circuit**

	U	V	W
High side gate (HO turn-on/off)	R61/R99/D9	R62/R101/D10	R63/R118/D11
Low side gate (LO turn-on/off)	R64/R119/D12	R65/R120/D13	R66/R121/D14

Table 1: Gate drive resistor network

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IRMD2336DJ Protection Features

Motor Overcurrent Protection

Motor over-current protection is implemented using a dc link shunt resistor (R60) placed between power ground (COM pin) and logic ground (VSS pin) as shown in Figure 6. The ITRIP signal from the shunt has an input RC filter (R38, C37) to reject power inverter noise. The IRS2336DJ has a comparator that generates a shutdown signal when the ITRIP pin voltage exceeds the ITRIP threshold ($V_{IT,TH+}$). An internal noise filter rejects pulses shorter than 400ns to avoid spurious trips due to diode reverse recovery current. The shutdown signal turns off all six outputs and pulls the $\overline{FAULT}$ pin & RCIN pin low. When the over-current condition is cleared, the fault remains latched until reset by the voltage on the RCIN.

Under-voltage protection circuits

The IC monitors the supply voltage on the V_{CC} pin. It turns off all six outputs and pulls the $\overline{FAULT}$ pin low when V_{CC} falls below a minimum threshold (V_{CCUV-}). This fault is not latched but is cleared once V_{CC} goes above the positive going threshold (V_{CCUV+}). The IC also features UVLO protection for all 3 VBS floating supplies; However, a VBS UVLO condition does not trigger a fault reporting i.e. $\overline{FAULT}$ pin is not pulled low under VBS UVLO. Under a VBS UVLO condition, the corresponding gate driver output is terminated until the VBS UVLO condition is cleared.

IRMD2336DJ Fault Reporting

The $\overline{FAULT}$ pin of the IC is used to communicate a fault situation to the digital control IC. The $\overline{FAULT}$ pin, which is normally pulled up to 3.3V using pull up resistor, is connected to the GATEKILL pin on the IRMCF341. When the IC detects a fault situation (either due to VCC UVLO or ITRIP) all gate driver outputs are shut-down and the $\overline{FAULT}$ pin is pulled low and this triggers the GATEKILL function of IRMCF341 causing all PWM outputs of IRMCF341 to be shutdown. Fault reporting is performed only for the following:

- Motor overcurrent (ITRIP)
- VCC supply UVLO

It is again noted that VBS UVLO does not trigger a fault situation.

Automatic Reset after ITRIP Fault

Automatic fault reset provided by the HVIC is based on the time constant (RC_{reset}) of the passive network on the RCIN pin. An RC network (R39, C38) between the RCIN pin and VCC supply allows an automatic reset of the ITRIP fault. The capacitor on the RCIN pin is held low as long as the ITRIP comparator input exceeds the ITRIP voltage threshold. When the ITRIP fault condition clears, the capacitor is allowed to charge up. The ITRIP fault is reset when the capacitor voltage exceeds a minimum threshold ($V_{RCIN,TH+}$). The RCIN auto-reset time can be calculated from the following equation:

$$t = R_{39} \cdot C_{38} \ln\left(\frac{V_{cc}}{V_{cc} - V_{RCinTH+}}\right)$$

The reference design auto reset time is approximately 1.6ms for V_{cc}=15V, $V_{RCinTH+=}$8V and R_{39}=2MOhm, C_{38}=1nF. The on resistance of the reset FET on the RCIN pin cannot be neglected so a relatively small capacitor should be used so that it becomes fully discharged before the fault is released.

Enable Function

The IC features a dedicated EN pin to provide enable/disable functionality with the functionality enabled when EN pin is biased high. In the IRMD2336D reference design, EN pin is tied to 3.3V DC bus potential to always enable operation.

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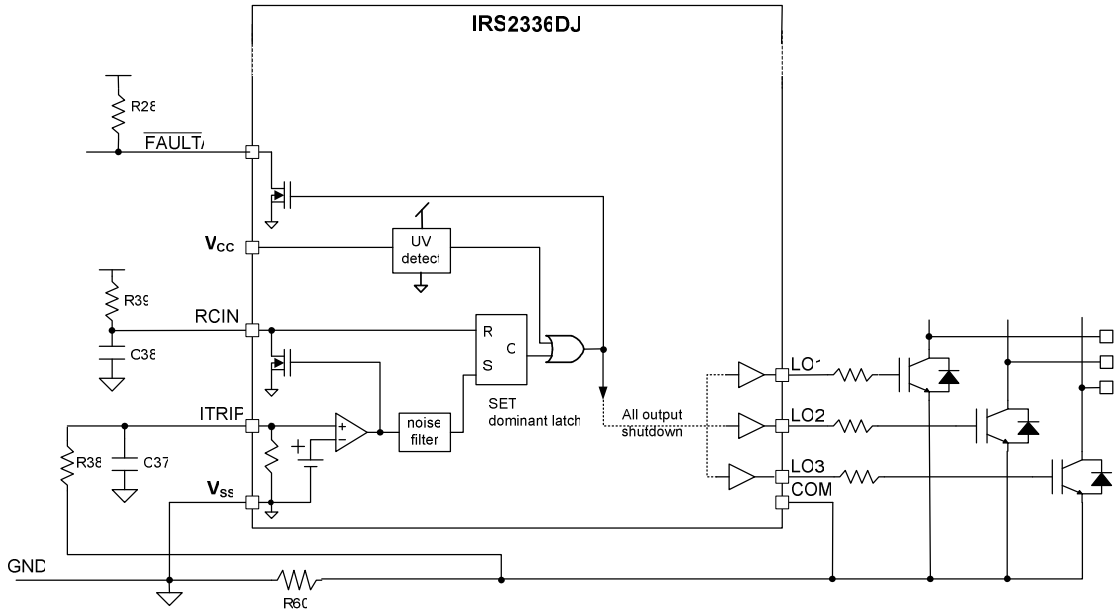


Figure 6: Protection circuits, Fault Reporting & Automatic Reset after ITRIP fault

PWM input to IRS2336DJ & Connection of an external system controller

IRMD2336DJ is configured by default to use the PWM signals from the on-board IRMCF341 controller for the IRS2336DJ HVIC. The default configuration connects the IRMCF341 digital control IC to the IRS2336DJ by shorting pins 5-6, 7-8, 9-10, 11-12, 13-14, 15-16, 17-18 on connector P1 shown in Figure 7. Since the IRS2336DJ is based on Active Low logic, the PWM inputs to the HVIC in IRMD2336DJ are connected to 3.3VDC using pull-up resistors (R26 to R32).

An external controller can easily be invoked for driving the IRS2336D by removing the shorting connections on the 20 pins DIL connector P1 and connecting the external PWM signals to the odd numbered pins on P1. It is reiterated that the correct PWM inputs that is appropriate for the “Active Low” logic of IRS2336DJ must be maintained.

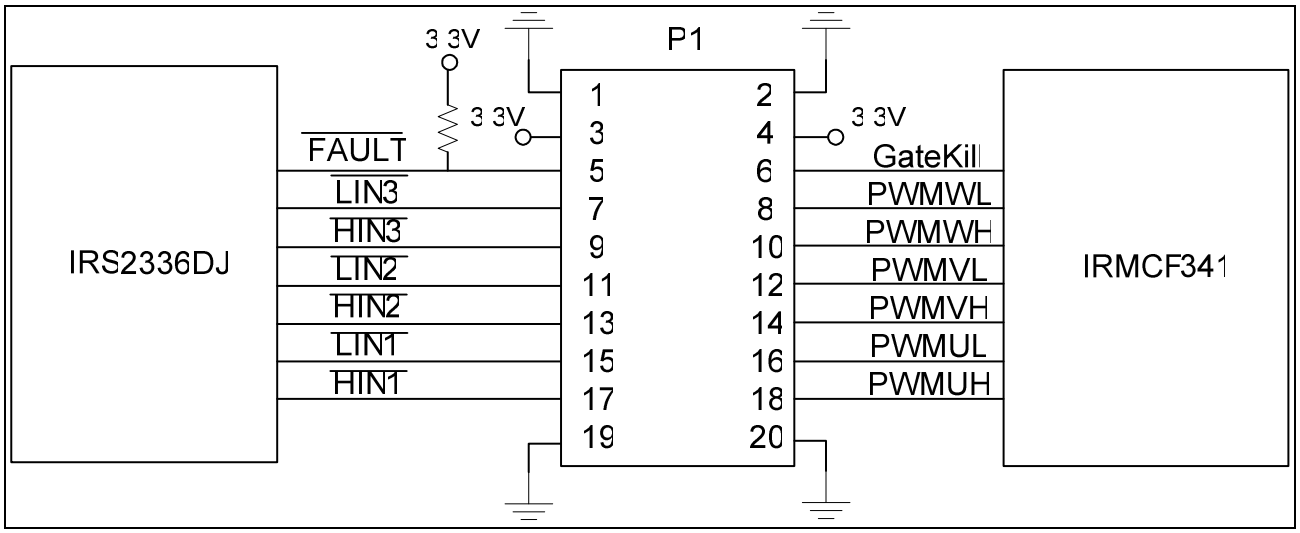


Figure 7: 20-pin connector P1

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Test Points for Investigation

The reference design is provided with ample test points to probe the different pins of the gate driver IC and inverter circuit. The following table provides a summary of the most useful test-points around the IRS2336D HVIC and their associated functionality.

Test Point #	Test Point Name	Remark
TP28, 29, 30	U, V, W	Motor Phase nodes (also negative terminals of bootstrap supply voltage)
TP37, 38 & 39	VB3, VB2, VB1	Boot-strap supply voltage positive terminal
TP9, 10, 11	UH, VH, WH	PWM input to high-side channels of HVIC (HIN1, HIN2 & HIN3)
TP31, 32, 33	UG, VG & WG	Gate of high-side IGBTs
TP7, 8, 9	UL, VL, WL	PWM input to low-side channels of HVIC (LIN1, LIN2 & LIN3)
TP34, 35, 36	UG/, VG/, WG/	Gate of low-side IGBTs
TP24	COM	Common emitter of low-side IGBTs (also Positive terminal of current shunt resistor)
TP22	GK	$\overline{FAULT}$ pin of IRS2336D (also Input to IRMCF341 GATEKILL pin)
TP2	IFB	Motor current feedback
TP4	DCP	DC Bus
TP14, 15, 25, 26, 27	GND	Logic ground of IRS2336D (VSS pin) & DC Bus return
TP103	VCC	VCC pin of IRS2336D

Table 2: List of Test Points

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IRMD2336DJ – Operating Instructions

The following hardware is supplied with the IRMD2336DJ reference design kit

- IRMD2336DJ board with heat sink
- IRMD2336DJ GUI Software CD-ROM
- PC USB-serial cable & driver CD-ROM

Visually inspect IRMD2336DJ board to check for loose wiring, loose or damaged components or other abnormalities before proceeding.

STEP 1: Software Installation

The reference design kit is supplied with IRMD2336DJ GUI v1.0 software intended to support the evaluation of IRS2336DJ HVIC. The on board digital control IC (IRMCF341) generates the inverter PWM signals and can run a three phase induction motor using open loop V/F or Volts-per-Hertz control. This software is the GUI that allows the specification of the motor, inverter and system parameters.

The software tool is distributed on a CD-ROM. Load the CD into the CD-ROM drive on a PC and if installation does not start double-click on the .exe installation file. The automated procedure installs all necessary software and documentation on the PC. The default location for the installation is "C:\Program Files\IR\IRMD2336DJ".

STEP 2: Test Bench Connection

1. Connect the ac power cables to Earth (E), line (L) and neutral (N) terminals of J1 connector. Prepare a power contactor switch rated at 250V/10A in series with AC power cables if necessary.



ATTENTION: Turn off or unplug the power before making any connections to board. All circuits on the board must be considered as 'live' with respect to the safety earth so please use extreme caution when making connections to circuit board. It is recommended to isolate the oscilloscope ground when making circuit waveform measurements.

2. Connect the motor windings to the U/V/W terminals of connector J1. If needed, connect the motor frame to the Safety Earth connection available on the E terminal of connector J1.
   NOTE: GND terminal of connector J1 is NOT to be used for the purpose of safety grounding.
3. Connect the RS-232 cable between the DB-9 connector J6 on IRMD2336DJ board and an available COM port (USB port) on your PC. The RS-232 serial connector is galvanically isolated from the circuit board ground so the user can safely connect a PC to the board.

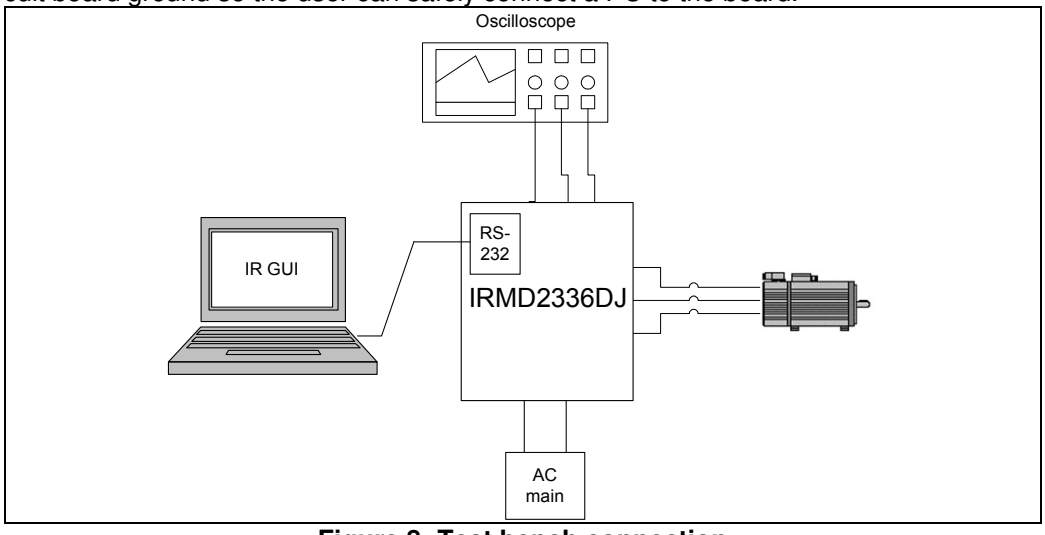


Figure 8: Test bench connection

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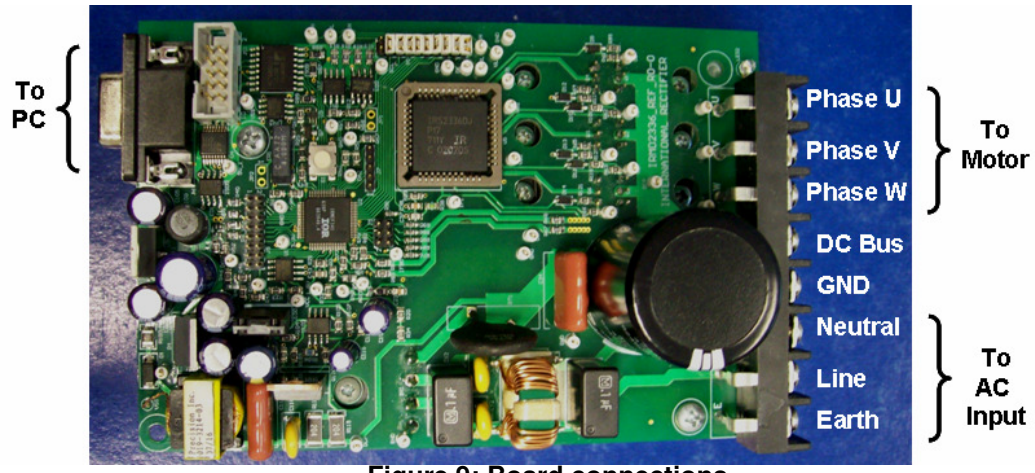
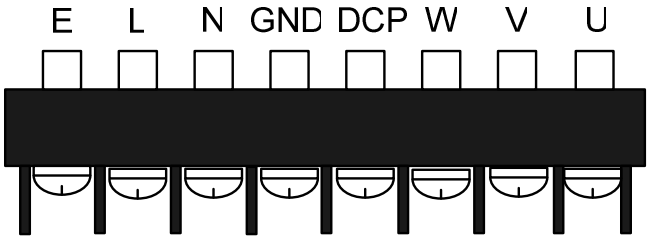


Figure 9: Board connections



E	Safety Earth (connected to the heatsink)
L	AC line input
N	AC neutral input
GND	DC bus ground
DCP	Positive DC bus
U	motor U phase
V	motor V phase
W	motor W phase

Figure 10: 8-pin connector J1



ATTENTION: The GND terminal of connector J1, called DC Bus Ground, is biased to the negative DC bus voltage potential of IRMD2336DJ, which connects to the ac power line input via the input rectifier. The GND terminal is NOT to be confused with safety ground of the system. Instead, the E terminal of connector J1, called Safety Earth, is to be used for purpose of safety grounding. Failure to follow these instructions can result in personal injury or death.

STEP 3: Powering the Board

Connect the power cables to 220VAC mains and turn-on the power switch. There are 2 on-board LEDs for diagnostic purposes as shown in Fig.11.

1. Check if LED2 is lit in red after you apply AC power. LED2 is connected to the dc bus and indicates that power is connected to the board and the on-board switching mode power supply is active.
   NOTE: Never attempt to service the board or engage/disengage any connections when LED2 is lit since it indicates the presence of high-voltages on the board.
2. Check if LED1 is a slowly flashing green. LED1 is driven by the digital control IC IRMCF341 controller. It is lit red when a fault is detected and slowly flashes green when IRMCF341 is in proper operational status. If LED1 is lit red after powering the board then it indicates one of the following:
   i. *Under-voltage fault:* This occurs if rectified DC bus voltage is less than 120V; Check DC Bus & AC input voltage levels and ensure DC bus is greater than 120V. Then proceed to Step 4. LED1 will be a flashing green once Step 4 is completed.
   ii. *Over-voltage fault*: This occurs if rectified DC bus voltage is greater than 360V; Check DC Bus & AC input voltage levels and ensure that DC bus is less than 360V. Then proceed to Step 4. LED1 will be a flashing green once Step 4 is completed.
   iii. *Reference Design Configuration Error:* Contact IR Support.

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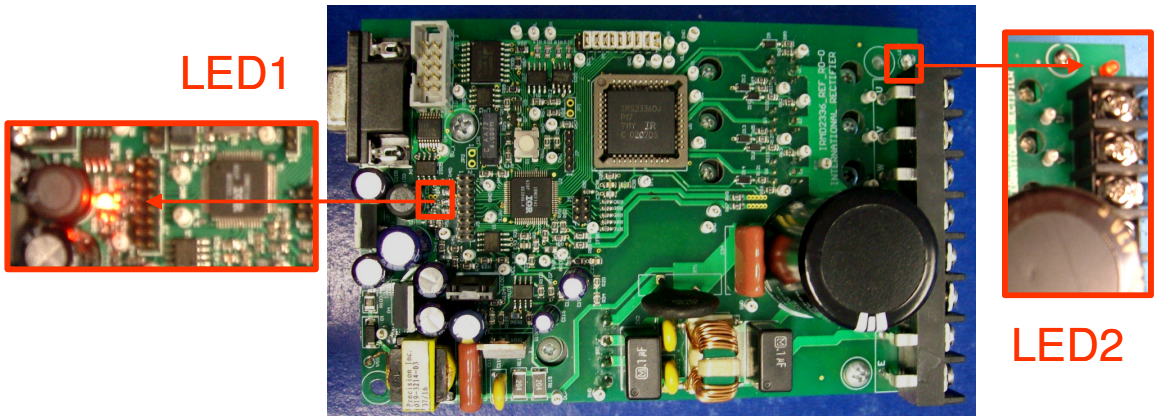


Figure 11: Location of diagnostic LEDs in IRMD2336DJ

STEP 4: Running the Software GUI

Step 4a: Start the GUI software program on PC

Start the GUI Software by clicking the desktop icon or double-clicking .exe file.

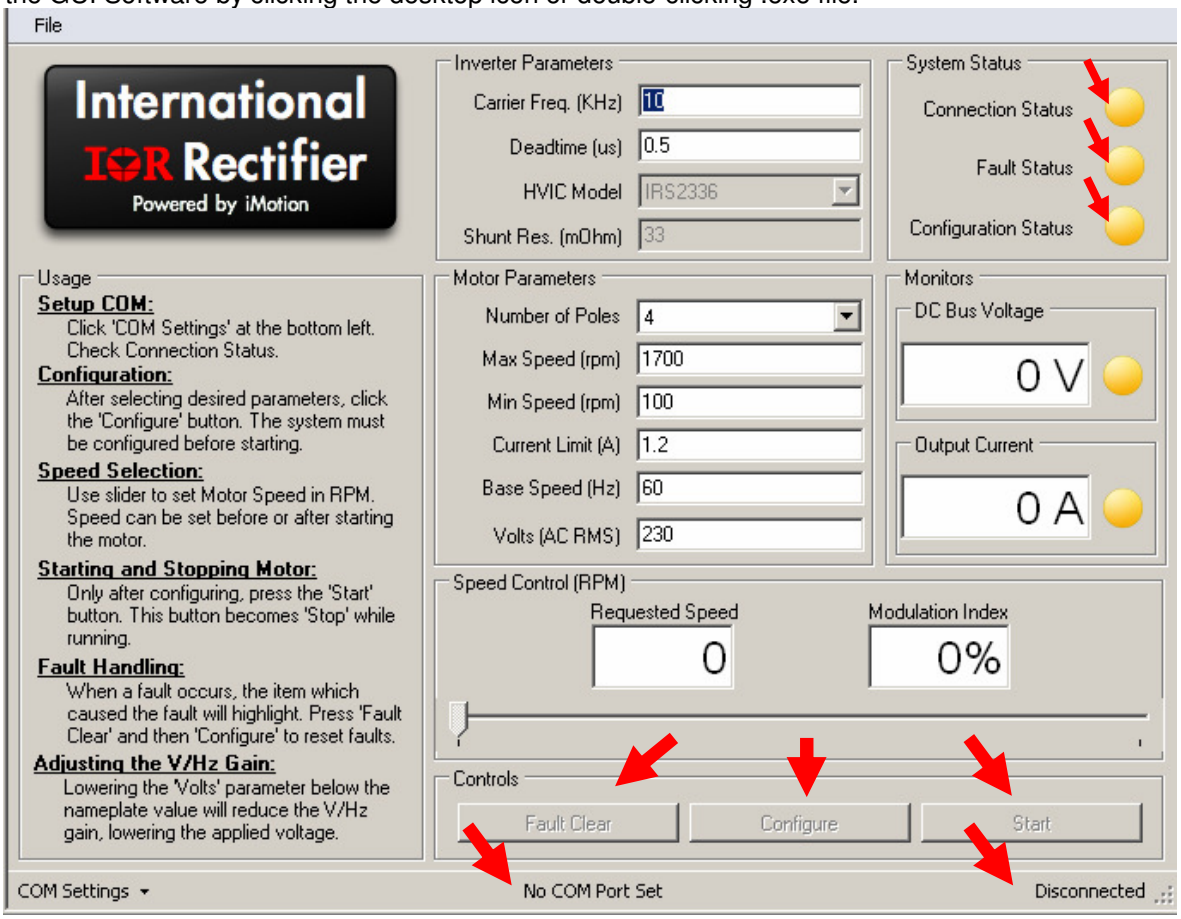


Figure 12: Software GUI before establishing communication between PC & IRMD2336DJ

Note the following:

- All 3 icons in System Status section of GUI (Connection Status, Fault Status & Configuration Status) are yellow in color.
- All buttons in the Controls section of GUI are disabled

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- At the bottom of the GUI, the messages “No COM Port Set” & “Disconnected” are displayed

Step 4b: Selecting the COM port (RS-232)

The software on the PC communicates with the digital control IC on-board using a COM port. It is necessary to select the COM port on the PC to which the USB cable is connected to run the GUI software. COM port setting can be selected by clicking on “COM Settings” at the bottom-left of the GUI window.

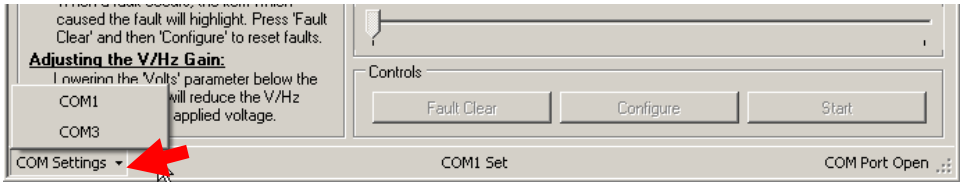


Figure 23: COM port selection dialog

When the correct COM port is selected and after communication is successfully established between the PC and digital control IC,

- the “Connection status” & “Fault status” icons in the System Status section should change colors from yellow to green,
- the Monitor section icons should change color from yellow to green and provide real time information
- the “Fault Clear” & “Configure” buttons in Controls section are enabled
- At the bottom of the GUI, the messages “COM# Set” (where # is the appropriate COM port number) and “COM Port UP” are displayed.

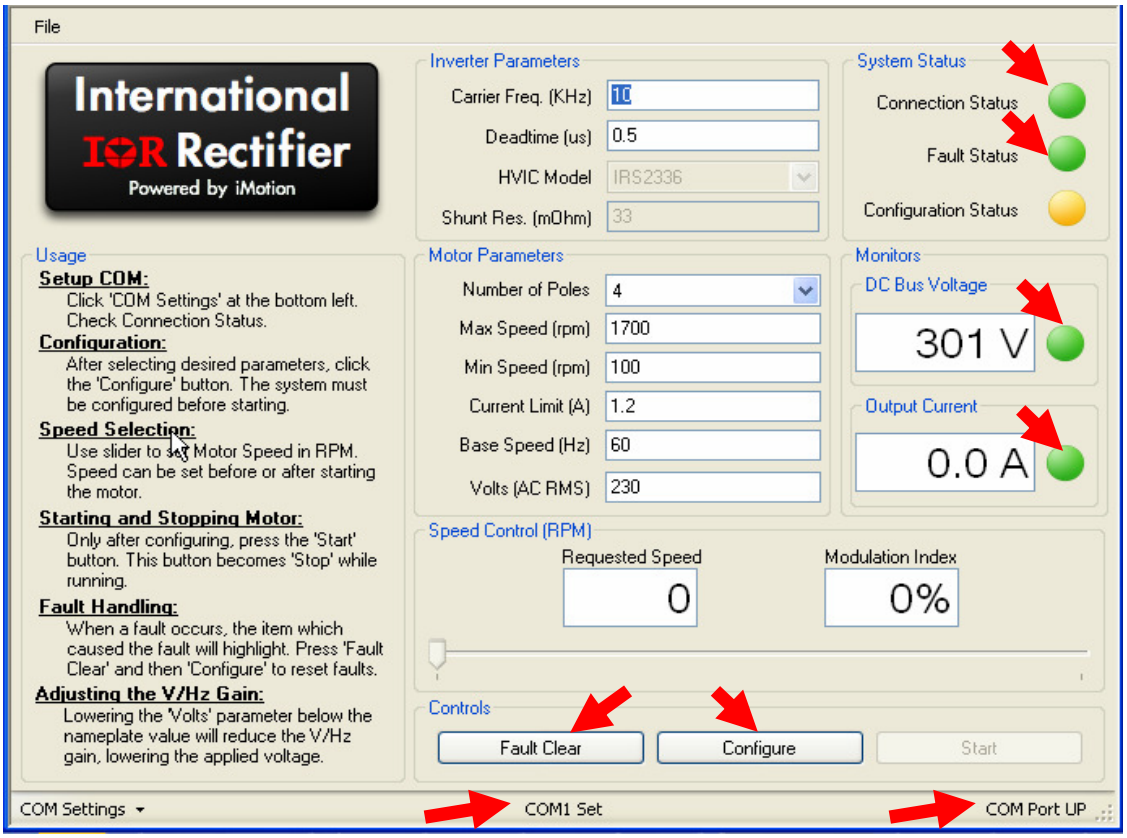


Figure 14: Software GUI after establishing communication between PC & IRMD2336DJ

NOTE: If any faults occurred during STEP 3 and caused LED1 to be lit red, then the “Fault Status” and Monitor section icons in the GUI will also appear red with the reason for the fault (“Over-voltage Fault” OR “Under-voltage Fault”) displayed at the bottom of the GUI. As long as the reason for the fault has been determined and rectified in STEP 3, please continue to STEP 4c.

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Step 4c: Configuring the Hardware

After the selection of inverter and motor parameters on the GUI click on the 'Configure' button to load them to the digital control IC on the IRMD2336DJ board. This step is absolutely necessary before the motor can be started. **Please refer to "Software GUI Reference Guide" section for more information about GUI parameters and the associated system implications.**

Upon successful configuration, the

- the "configuration status" icon in the System Status section should change colors from yellow to green
- the "Start" button in Controls section is enabled

NOTE: Remember to press the configure button every time after a change is made to any GUI parameter.

NOTE: The DC bus voltage must remain constant after pressing the configure button, otherwise the control algorithm will not operate as expected. Remember to press the configure button after every time the DC bus level is altered.

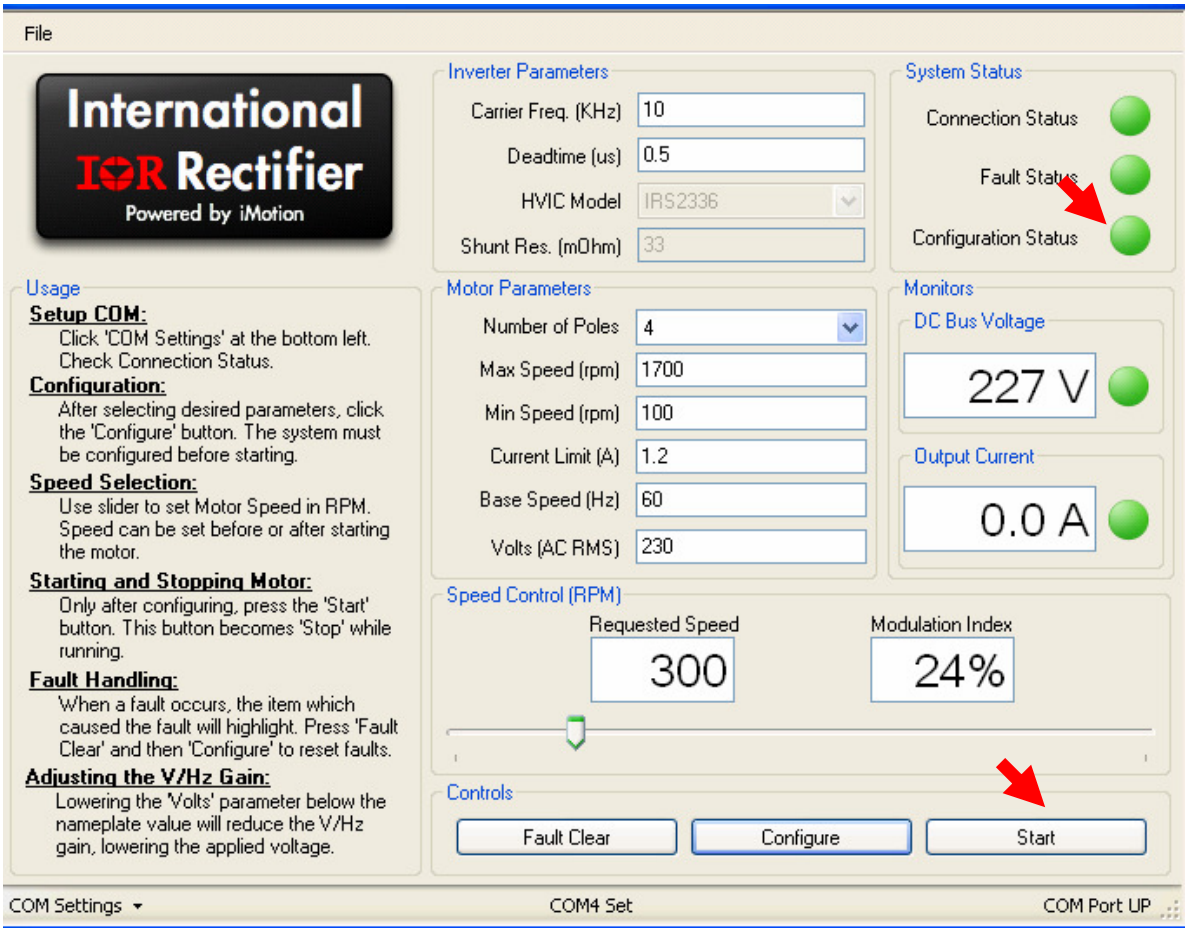


Figure 15: Software GUI after successful configuration of IRMD2336DJ

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Step 4d: Starting, Running & Stopping the Motor

To start the motor, press the "Start" button in the Controls section. The motor will start and accelerate to the specified rotation speed. Further, the "Start" button in the Controls section of the GUI will toggle into a "Stop" button.

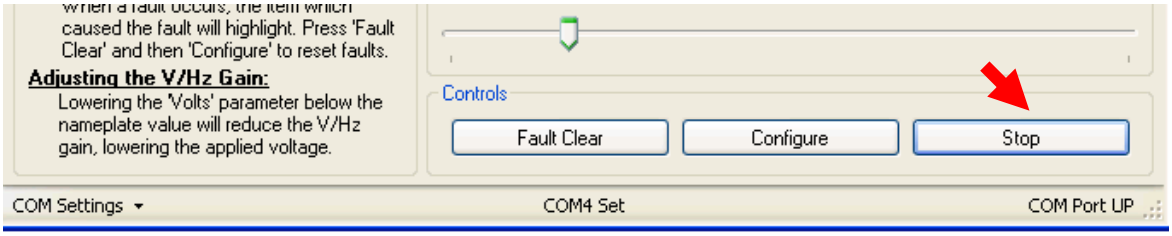


Figure16: Software GUI while running the motor using IRMD2336DJ

While running, the motor speed can be changed real-time by using the slider to set the new speed. To stop the motor, simply press the "Stop" button. The motor will coast to a full stop. Further, the "Stop" button will toggle back to "Start".

Software GUI Fault Handling Instructions

A fault situation may be triggered either by the software GUI or hardware (digital control IC). **Please refer to the "Software GUI Reference Guide" section for more information about the fault conditions that can be encountered during operation.** In both cases, when a fault is encountered during motor operation, the GUI immediately stops the motor. Further,

- the "Fault Status" icon in System Status section changes to red
- If any of the Monitors are related to the fault condition, then the appropriate Monitor icon also changes color to red
- the "Start" button in Controls Section is disabled
- the fault condition is displayed at the bottom of the GUI

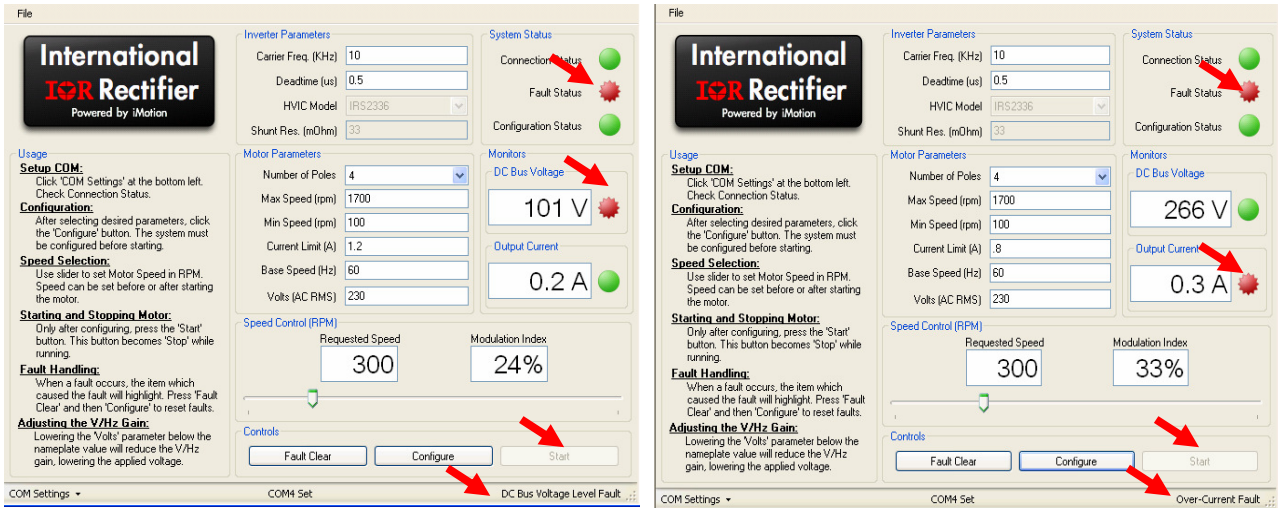


Figure17: Software GUI during 2 different fault situations

To clear the fault and restart motor, the following actions are performed in the specified sequence

- Press the "Fault Clear" button in Controls Section; the "Fault Status" icon & the respective system monitor icon in System Status section then change from red to green
- Reconfigure the motor as outlined in Step 4b
- Proceed to running the motor as outlined in Step 4c

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IRMD2336DJ – Software GUI Reference Guide

Motor parameters

- **Number of poles** – The number of poles defines the ratio of the electrical to mechanical frequency in the induction motor (# of poles = Electrical Frequency/Mechanical Frequency). This is selected from the drop down menu in the GUI. Only even number values are listed in the drop down menu since the motor poles come in pairs.
- **Max speed** – This is the maximum speed that the motor can run. The motor speed cannot be set faster than this value. This is entered in revolutions per minute (RPM). This parameter can be obtained from the motor nameplate.
- **Min speed** – This is the minimum speed that the motor can run. The speed cannot be set lower than this value. This is entered in revolutions per minute (RPM).
- **Current Limit** – This is the maximum RMS current (phase current in the motor) that the system will allow in the motor before the GUI triggers a fault and stops the motor. This is entered in amperes (A). This parameter can be obtained from the motor nameplate.
- **Volts** – This is the rated RMS voltage (L-L) of the induction motor. This parameter is the voltage used in the V/Hz control algorithm. This is entered in Volts (V). This parameter can be obtained from the motor nameplate.

  NOTE: When the configure button is pressed this value is sampled along with the current DC bus. The DC bus must remain constant after pressing the configure button, otherwise the control algorithm will not operate as expected.
- **Base Speed** – This is the rated electrical frequency for running the induction motor. This parameter is the Hertz value used in the V/Hz control algorithm. This is entered in Hz. This parameter can be obtained from the motor nameplate.

Inverter parameters

- **Carrier frequency** - User selectable input of PWM frequency of inverter. This is entered in KHz in the range from 5kHz to 35khz.
- **Dead time** – The dead time that will be present between switching high and low side IGBTs. This is entered in μs. Typically deadtimes are less than 1usec.

System Status

- **Connection status** – Indicates if the connection between software and IRMCF341 is working and active. Green indicates successful connection, while yellow indicates lack of connection. Other System status icons also remain yellow when there is no connection.
- **Fault Status** – Indicates if any faults are present in the system. Green indicates fault-free status while red indicates occurrence of a fault. The fault condition is displayed at the bottom of the GUI and the associated Monitor icon is also lit red, if applicable. Faults can be cleared by pressing the Fault Clear button. If the fault remains even after pressing the Fault Clear button then it indicates that the fault situation is continuing to persist. Table 3 shows a list of all the faults that can be encountered.
- **Configure Status** – Indicates if any parameters have been modified since the last configure. If this indicator is yellow, the configuration button should be pressed again prior running the motor. It is recommended to press the configuration button every time before starting and running the motor.

Control

- **Fault clear** – This button will clear all of the faults present in the system. If the fault remains after pressing this button it indicates that the fault situation is continuing to persist. This button will be disabled when a PC-to-hardware connection is not present and when the motor is running. Shut-down power and restart GUI to resume operation.
- **Configure** - This button will configure the hardware with the parameters that have been selected in the GUI. This step is not done automatically. Remember to configure the hardware every time a

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parameter is altered or DC bus voltage level is changed. This button will be disabled when a PC-to-hardware connection is not present and when the motor is running. Shut-down power and restart GUI to resume operation.

- **Start/Stop** – This toggle-type button starts and stops the motor. During motor-start, an acceleration control gradually ramps the motor speed to the value in "Requested Speed" field.

Fault Condition	Fault Type (source)	Explanation of Fault	Fault Trip Level
Over-voltage Fault	Hardware Generated (by Digital IC)	Indicates DC bus over-voltage condition at system power-up (NOTE: this fault occurs only during power up, when GUI is still unconfigured)	DC Bus Voltage > 360V
Under-voltage Fault	Hardware Generated (by Digital IC)	Indicates DC bus voltage under-voltage condition at system power-up (NOTE: this fault occurs only during power up, when GUI is still unconfigured)	DC Bus Voltage < 120V
DC Bus Voltage Level Fault	Hardware Generated (by Digital IC)	Indicates either a DC bus over-voltage or under-voltage condition (NOTE: this fault occurs after GUI has been configured)	DC Bus Voltage > 360V OR DC Bus Voltage < 120V
Gatekill Fault	Hardware generated (by HVIC)	Indicates ITRIP fault or VCC UVLO fault occurring in IRS2336D; Gatekill fault is triggered by $\overline{FAULT}$ pin of IRS2336D	VCC < 8.2V (Typ) AND/OR V(R60) > 14A (Typ)
Overcurrent Fault	Software Generated	Indicates that motor current fault	RMS Motor Current calculated by GUI > "Current Limit"
System Error	Software Generated	Indicates out-of-bounds errors, contact IR support	-

Table 3: List of errors obtainable during testing & associated conditions

Monitors

- **DC bus voltage –** The instantaneous voltage of the DC bus. The over-voltage fault is encountered if the DC bus increases beyond 360V. The under-voltage fault is encountered if DC bus is less than 120V.
- **Output current –** The rms motor current calculated by software. It is dependent on the shunt resistor value defined on the system parameter. The over-current fault is encountered if the calculated value exceeds the "Current Limit" parameter.

Speed Control

- The START button in the GUI starts the motor and gradually ramps the motor speed to the specified value in "Requested Speed" field. In addition, the GUI has a slider to adjust the motor if it is already running. An acceleration control is included to gently accelerate to the requested speed and is not user definable.

- A modulation index is shown just above the speed slider. This index will not go beyond 100%, nor can a speed that will cause a modulation index greater than 100% be selected. This causes the slider lock before reaching its maximum speed. If a greater speed is required, increase the DC bus voltage and press configure. This will decrease the associated modulation index for a given speed.

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IRMD2336DJ – Circuit Schematics

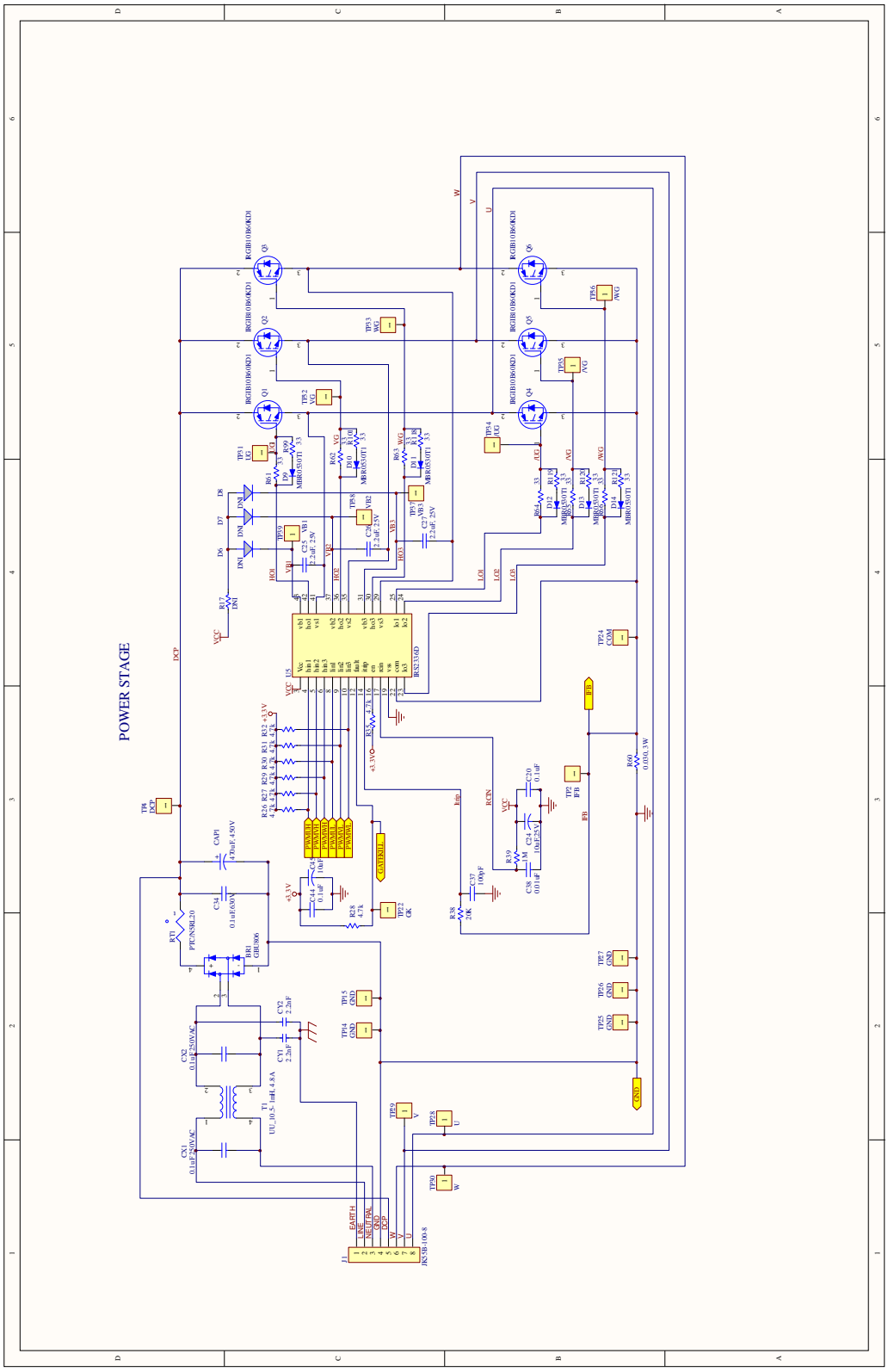


Figure 18: IRMD2336DJ Power Stage Circuit Schematic

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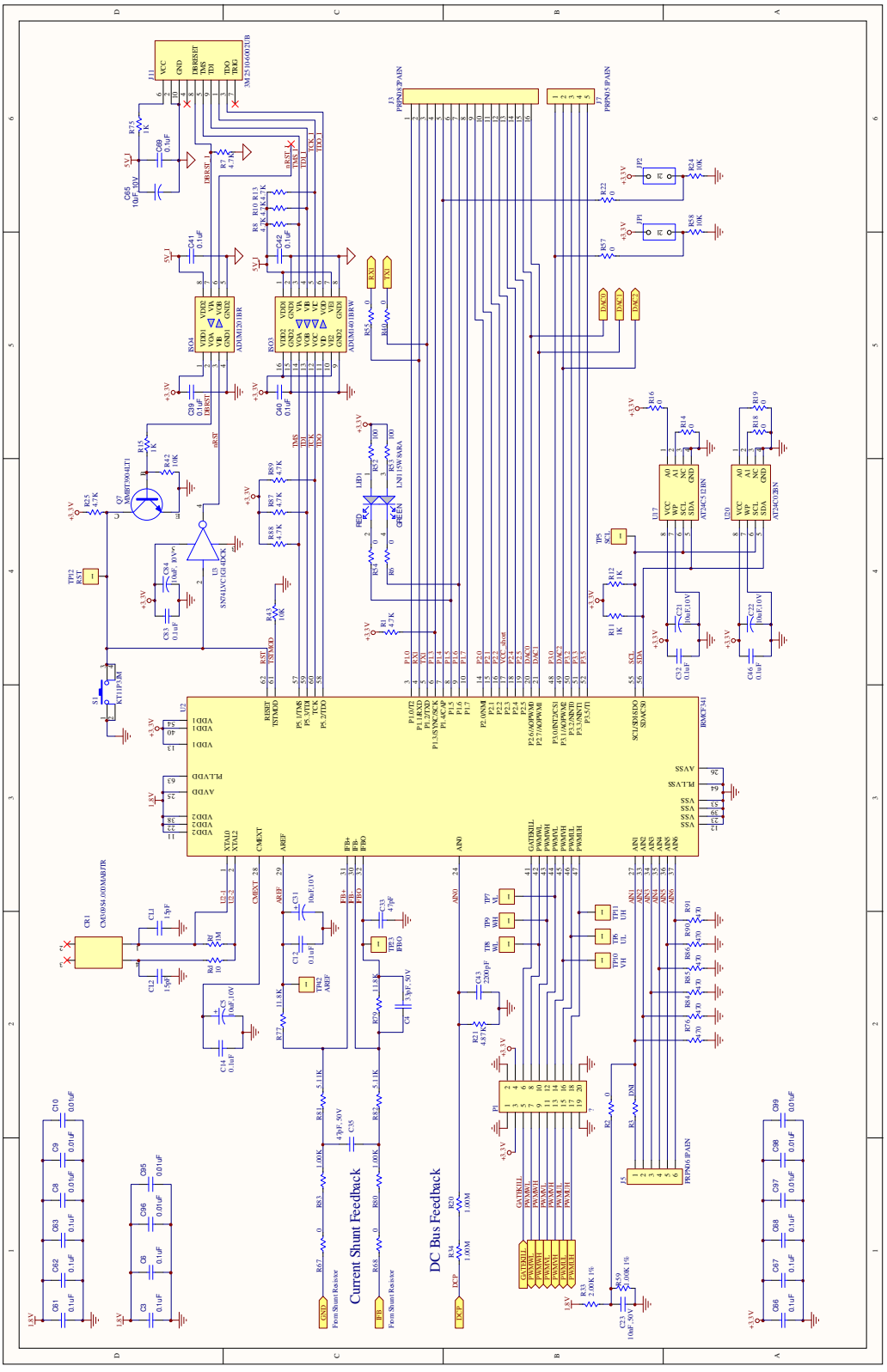


Figure 19: IRMD2336DJ Digital Control & Communications Circuit Schematic

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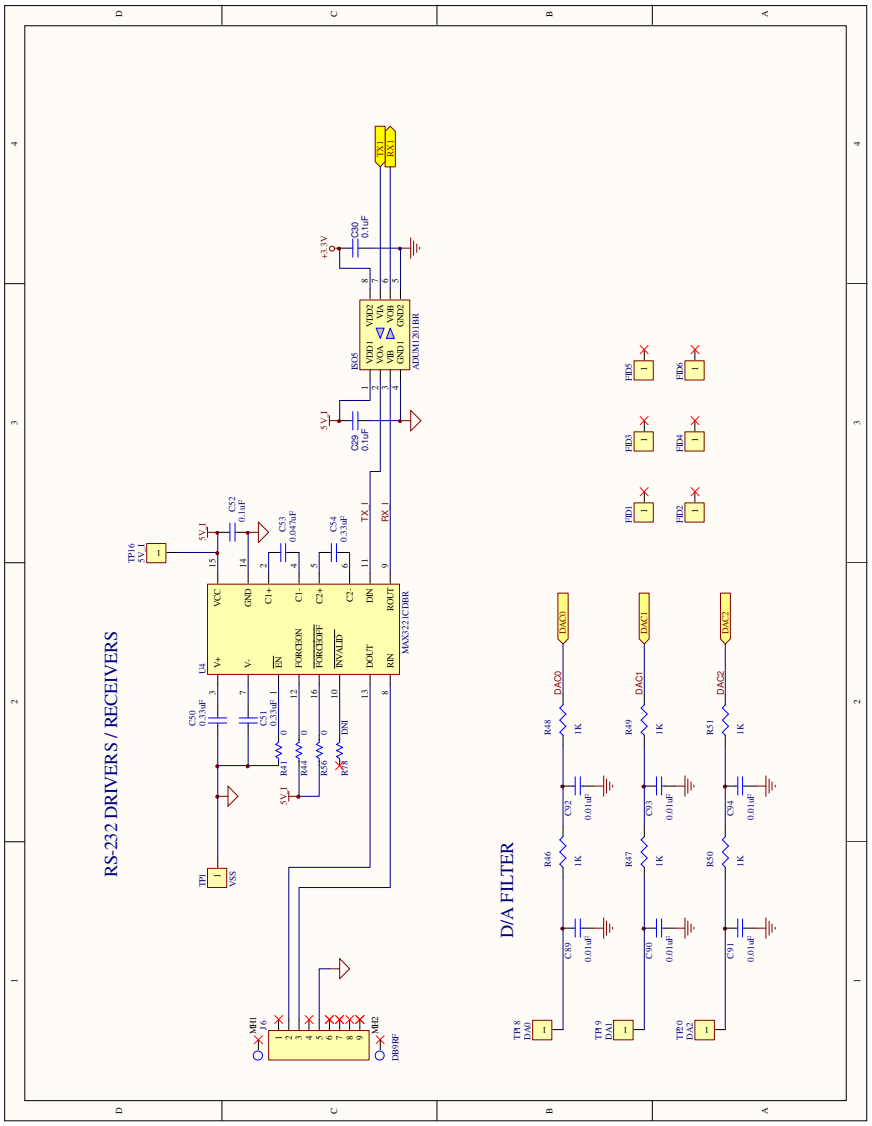


Figure 20: IRMD2336DJ RS-232 Drivers & Receivers Circuit Schematic

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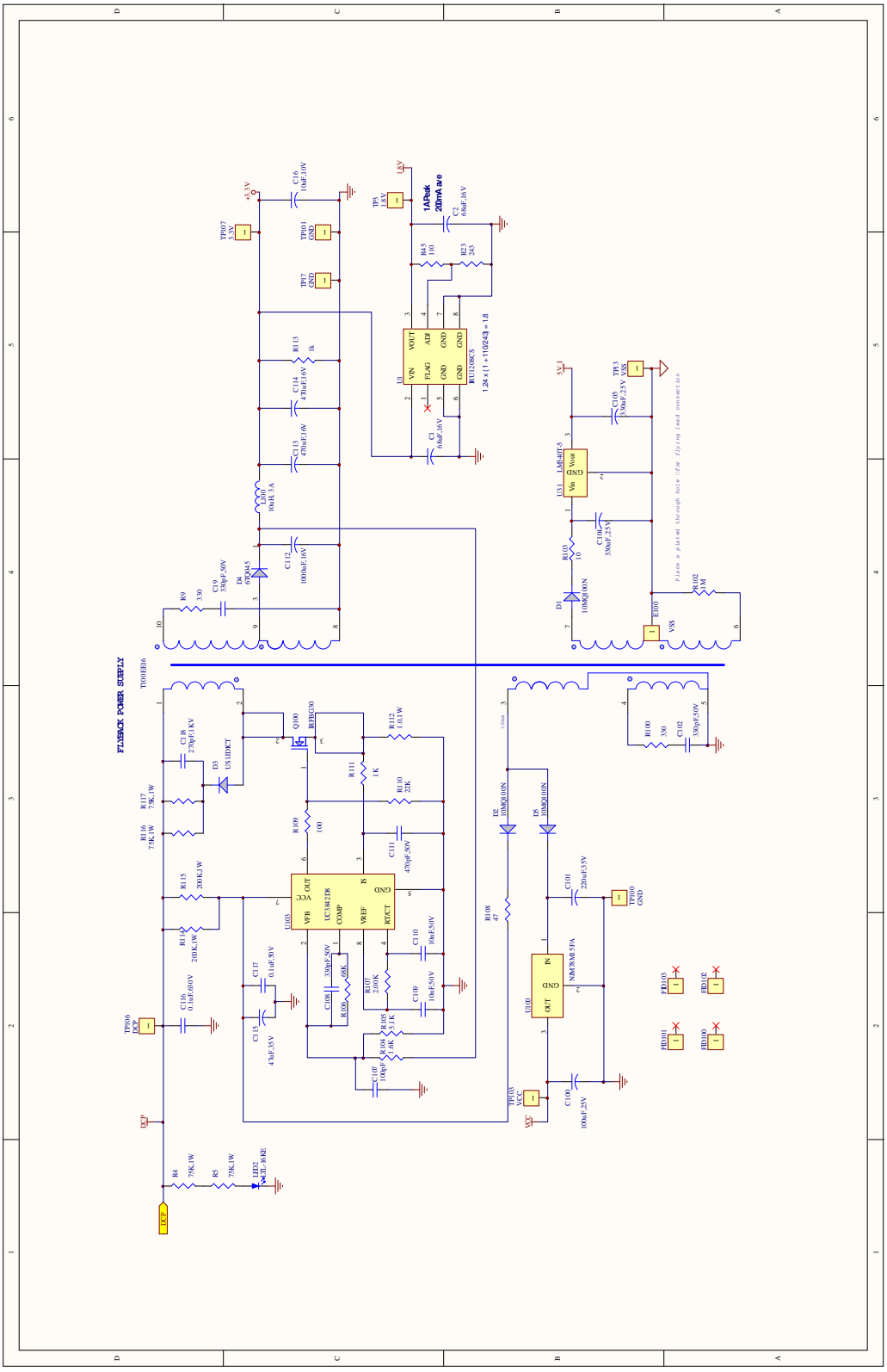


Figure 21: IRMD2336DJ DC-DC Converter Low Voltage Power Supply Circuit Schematic

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IRMD2336DJ – Bill of Materials

#	COMPONENT DESCRIPTION	MANUFACTURER & PART #	QTY	DESIGNATOR
1	PCB	IR IRMD2336DJR0.2	1	
2	CONN, HDR,2x5 3M .100" x .100" 4-Wall Header,Standard,Straight Through-Hole,10 Contacts,2510-6002UB	3M 2510-6002UB	1	J11
3	CAP SMT, 0.01uF 0603 CER 50V 10% NPO/COG		14	C8-C10,C89-C99
4	CAP SMT, 0.1uF 0603 CER 50V 10% X7R		20	C3,C6,C12,C14,C29,C30,C32,C39-C42,C44,C46,C61-C63,C66-C69
5	CAP SMT, 15pF 0603 CER 50V 5% NPO/COG		2	CL1,CL2
6	CAP SMT, 33pF 0603 CER 50V 5% NPO/COG		1	C4
7	CAP SMT, 47pF 0603 CER 50V 5% NPO/COG		2	C33,C35
8	CAP SMT, 10000pF 0805 CER 50V 10% X7R		4	C23,C38,C109,C110
9	CAP SMT, 47nF 0805 CER 50V 10% X7R		1	C53
10	CAP SMT, 0.1uF 0805 CER 50V 10% X7R		4	C20,C52,C83,C117
11	CAP SMT, 0.33uF 0805 CER 50V 10% X7R		3	C50,C51,C54
12	CAP SMT, 100pF 0805 CER 50V 5% NPO/COG		2	C37,C107
13	CAP SMT, 2.2uF 0805 CER 25V +80/-20% Y5V		3	C25-C27
14	CAP SMT, 2200pF 0805 CER 50V 5% NPO/COG		1	C43
15	CAP SMT, 330pF 0805 CER 50V 10% X7R		3	C19,C102,C108
16	CAP SMT, 470pF 0805 CER 50V 10% X7R		1	C111
17	CAP SMT, 10uF 3216 (A) TANT 16V 10%	KEMET T491A106K016AT T491A106K016AG	8	C5,C16,C21,C22,C31,C45,C65,C84
18	CAP SMT, 10uF 6032 TANT 25V 10%		1	C24
19	CAP SMT, 68uF 7343 TANT 16V 20%		2	C1,C2
20	CAP THR, 1000uF, AL ELEC 16V 20%		1	C112
21	CAP THR, 47uF, AL ELEC, 35V 2mmLS	DIGIKEY P5164	1	C115
22	CAP THR, 100uF, AL ELEC, 25V 2mmLS		1	C100
23	CAP THR, 220uF AL ELEC, 35V POL, (0.140"ls/3.5mm)	PANASONIC EEU-FC1V221L	1	C101
24	CAP THA, 330uF, AL ELEC 25V		2	C104,C105
25	CAP THR, 470uF, AL ELEC 16V 20%		2	C113,C114
26	CAP THR, 470uF,ELEC 450V 20%	Panasonic EET-UQ2W471DA	1	CAP1
27	CAP THR, 0.1uF 300VAC 20% X1	Panasonic ECQ-U3A104MG	2	CX1,CX2
28	CAP THR, 2200PF 250VAC 20% Y2/X1	Panasonic ECK-NVS222ME	2	CY1,CY2
29	OSC SMT, 4.0MHZ CRYSTAL 18PF CM309S	Citizen CM309S4.000MABJTR	1	CR1
30	CONN, D-SUB, 9P RECPT RT ANGLE W/ JACK SCREWS	KYCON K22-E9S-NJ	1	J6
31	SINGLE SCHMITT-TRIGGER INVERTER	TI SN74LVC1G14DCK	1	U3
32	RES SMT, 0.033-OHM 1.5W 1% 2520	Caddock CD2520FC-0.033	1	R60
33	SMPS TRANSFORMER	Precision 019-3214-03	1	T100
34	RECT BRIDGE GPP 600V 8A GBU	DIODE GBU806	1	BR1
35	CONN, HDR, 1x2 BREAKAWAY, 0.025 SQ GD (0.100"/0.230")	SAMTEC TSW-102-07-S-S TSW-102-07-G-S	2	JP1,JP2
36	CONN, HDR,1x5	SULLINS PRPN051PAEN	1	J7
37	CONN, HDR, 2x10 PIN 0.025" SQ POST GOLD (0.100"/0.230")	SAMTEC TSW-110-07-S-D	1	P1
38	CONN, SHUNT, 2-PIN SHORTING SHUNT		10	@ P1
39	CONN, HDR,2x3	SULLINS PRPN032PAEN	1	J5
40	CONN, HDR,2x8	SULLINS PRPN082PAEN	1	J3

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#	COMPONENT DESCRIPTION	MANUFACTURER & PART #	QTY	DESIGNATOR
41	COMMON MODE EMI INDUCTOR	BURNON LCL-UF1125	1	T1
42	CONN, 8P 10mm	BURNON JK55B-100-8	1	J1
43	SWITCH SMT, SWITCH SPST MOM KEY J-LEAD SMD	ITT KT11P3JM Digikey CKN9003CT-ND	1	S1
44	LED, T1 RED DIFF	LITE-ON LTL-16KE	1	LED2
45	LED SMT, 1.6x1.25mm BI-COLOR GREEN/ORANGE	DIGIKEY P11142CT-ND	1	LED1
46	INDUCTOR HI CURRENT RADIAL 10UH	JW MILLER 6000-100K-RC Digikey M8616-ND	1	L100
47	RS-232 TRANSCEIVER IC 16L SSOP	MAXIM MAX3221CAE	1	U4
48	DIGITAL CONTROL IC	IR IRMCF341	1	U2
49	RES SMT, 470-OHM 1/16W 5% 0603		6	R76,R84,R85,R86,R90,R91
50	RES SMT, 0-OHM 1/8W 5% 0805		16	R2,R6,R14,R16,R18,R19,R22,R40,R41,R44,R54-R57,R67,R68
51	RES SMT, 1.0K-OHM 1/8W 1% 0805		15	R11,R12,R15,R46-R51,R59,R75,R80,R83,R111,R113
52	RES SMT, 1.0M-OHM 1/8W 1% 0805		4	R20,R34,R39,Rf
53	RES SMT, 1.6K-OHM 1/8W1% 0805		1	R104
54	RES SMT, 10-OHM 1/8W 1% 0805		1	Rd
55	RES SMT, 100-OHM 1/8W 1% 0805		3	R52,R53,R109
56	RES SMT, 10K-OHM 1/8W 1% 0805		4	R24,R42,R43,R58
57	RES SMT, 11.8K-OHM 1/8W 1% 0805		2	R77,R79
58	RES SMT, 110-OHM 1/8W 5% 0805		1	R45
59	RES SMT, 2.0K-OHM 1/8W 1% 0805		2	R33,R107
60	RES SMT, 20K-OHM 1/8W 1% 0805		1	R38
61	RES SMT, 22K-OHM 1/8W 5% 0805		1	R110
62	RES SMT, 243-OHM 1/8W 1% 0805		1	R23
63	RES SMT, 33-OHM 1/8W 1% 0805		12	R61-R66,R99,R101,R118-R121
64	RES SMT, 330-OHM 1/8W 1% 0805		1	R100
65	RES SMT, 4.7K-OHM 1/8W 1% 0805		17	R1,R7,R8,R10,R13,R25-R32,R35,R87-R89
66	RES SMT, 4.87K-OHM 1/8W 1% 0805		1	R21
67	RES SMT, 47-OHM 1/8W 5% 0805		1	R108
68	RES SMT, 5.11K-OHM 1/8W 1% 0805		2	R81,R82
69	RES SMT, 5.1K-OHM 1/8W 1% 0805		1	R105
70	RES SMT, 68K-OHM 1/8W 1% 0805		1	R106
71	RES SMT, 330-OHM 1/4W 5% 1206		1	R9
72	RES SMT, 1M-OHM 1/4W 1% 1206		1	R102
73	RES SMT, 10-OHM 1/4W 5% 1210		1	R103
74	RES SMT, 1-OHM 1W 5% 2512		1	R112
75	RES SMT, 200K-OHM 1W 5% 2512		2	R114,R115
76	RES SMT, 75K-OHM 1W 5% 2512		4	R4,R5,R116,R117
77	CAP THR, 0.1uF CER,630V	Panasonic ECQ-E6104KF Digikey EF6104-ND	2	C34,C116
78	CAP THR, CAP 270PF 1KV CERAMIC DISC GP 10%		1	C118
79	DIODE SCHOTTKY 100V 1.5A D-64	IR 10MQ100N	3	D1,D2,D5
80	DIODE ULTRA FAST SW 600V 1A SMA	DIODES INC US1J-13-F	1	D3

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#	COMPONENT DESCRIPTION	MANUFACTURER & PART #	QTY	DESIGNATOR
81	IC DIGITAL ISOLATOR 4CH 16-SOIC	ANALOG DEVICE ADUM1401BRW	1	ISO3
82	IC DIGITAL ISOLATOR 4CH 16-SOIC	ANALOG DEVICE ADUM1201BR	2	ISO4,ISO5
83	IC SEEPROM 2K 2.7V SO-8	ATMEL AT24C02N-10SI-2.7	1	U20
84	IC SEEPROM 512K 2.7V 8SOIC	ATMEL AT24C512N-10SI-2.7	1	U17
85	LDO REGULATOR IC	IR IRU1208CS	1	U1
86	IC SMT, CUR-MODE PWM CONT 8-SOIC	TI UC3842D8 DIGIKEY 296-11281-5-ND	1	U103
87	DIODE SMT, SCHOTTKY 30V 0.5A SOD-123	ON SEMI MBR0530T1G	6	D9-D14
88	TRANS SMT, NPN 40V 350MW SOT-23	DIODES INC MMBT3904-7-F	1	Q7
89	IC 15V POSITIVE REGULATOR TO220F	NJR NJM78M15FA DIGIKEY NJM78M15FA-ND	1	U100
90	IGBT W/DIODE 600V 16A TO220FP	IR IRGIB10B60KD1	6	Q1-Q6
91	MOSFET SWITCHING TRANSISTOR 1000V	IR IRFBG30	1	Q100
92	CURRENT LIMITER INRUSH	GE sensing CL-60 Digikey KC006L-ND	1	RT1
93	SOCKET SMT, 44L PLCC TIN SMD	TYCO/AMP 3-822516-1 DIGIKEY A97624CT-ND	NA	U5
94	IC, REG, +5V, 1.0A, TO-220---TO-220	NATIONAL SEMI LM340T-5.0 NOPB ST Microelectroni L7805CV Digi-Key 497-1443-5-ND	1	U31
95	DIODE SCHOTTKY 45V 6A D2PAK	IR 6TQ045	1	D4
96	MISC, TEST POINT MULIT PURPOSE MINI WHT	KEYSTONE 5002 DIGIKEY 5002K-ND	44	
97	COMPONENTS NOT POPULATED		6	D6,D7,D8,R3,R17,R78
98	HIGH VOLTAGE GATE DRIVER IC	IR IRS2336DJPBF	1	U5
99	HEATSINK	ZHENJIANG HAOYANG HEAT SINK COMPANY: DS-480	1	
100	insulating films for TO-220 heat sink		6	@Q1-Q6
101	HW, WASHER, M3, STEEL, SPLIT LOCK---LM7805	ALLTHREAD 1929--3-A-01AAA	6	@Q1-Q6
102	M3 * 8-3 M single screw, single-ended 3 M nuts, nylon, 6-column-shaped isolation		3	
103	M3 * 8-3 M single screw, single-ended 3 M nuts, copper / stainless steel, six-column-shaped isolation		1	
104	HW, SCREW, #4-40 x 5/16" MACHINE PAN HEAD PHIL ZINC PLATED	ALLTHREAD 1940--3--8-2A21A-0.5 PITCH	11	

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IRMD2336DJ - Specifications

Tc = 25°C unless specified

Parameters	Values	Conditions
Input Power		
Voltage	115V-230Vrms, -20%, +10%	
Frequency	50/60 Hz	
Input current	4A rms @nominal output	T_A =40°C, RthSA=1.9 °C/W
Input line impedance	4%~8% recommended	
Output Power		
Watts	400W continuous power	Vin=230V AC, f_{PWM}=10kHz, f_O=60Hz, T_A=40°C, RthSA=1.0 °C/W, Vertically mounted to help air flow
Current	3 Arms nominal, 9 Arms Overload	RthSA limits ΔTC to 10°C during overload
Host interface (RS232C)		
TXD, RXD	10V	Typical 57.6 Kbps, single ended
DC bus voltage		
Maximum DC bus voltage	400V	Should not exceed 400V more than 30 sec
Minimum DC bus voltage	120V	
Current feedback		
Current sensing device	33 mΩ dc link shunt	Single shunt reconstruction
Resolution	12-bit	PCB design may reduce the resolution
Latency	1 pwm cycle	
Protection		
Output current trip level	14 A peak, typical	Detection from shunt on negative DC bus
Short circuit delay time	Maximum 7 µsec	line-to-line short, line-to-DC bus (-) short
Critical over voltage trip	380 V	Zero vector insertion by digital controller
Over voltage trip	360 V	
Under voltage trip	120 V	
Power Devices		
IRGB10K60D1 x 6	Rated for 10A @100°C case with 10µs short circuit withstand capability	Integrated over-current protection
System environment		
Ambient temperature	0 to 40°C	95% RH max. (Non-condensing)

Table 4 IRMD2336DJ Electrical Specification

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WORLD HEADQUARTERS:
233 Kansas St., El Segundo, California 90245
Tel: (310) 252-7105

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