

# PV – 5208, 10208, 15208, 20208 & 30208 POWER CONVERSION SYSTEM FOR GRID – TIED PHOTOVOLTAIC APPLICATIONS

## TECHNICAL DESCRIPTION



**XANTREX**  
*Smart Choice For Power*



**Xantrex Technology Inc.**  
Distributed Industrial and Utility Markets  
161-G South Vasco Road  
Livermore, CA 94550  
Phone: 925/245.5400  
Fax: 925/245.1022

www.xantrex.com  
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## 1.0 General System Overview

This document describes Xantrex Technology' PV5208 through PV30208 power conversion systems for grid-connected photovoltaic applications. These inverters incorporate the advanced, insulated gate bipolar transistor (IGBT) based power electronics technology developed by Xantrex Technology. The power conversion system consists of a three-phase, 208 VAC pulse-width-modulated inverter, switchgear (optionally supplied by Xantrex) for isolation and protection of the connected AC and DC power systems, and an isolation transformer (also, optionally supplied by Xantrex). The following technical specifications and diagram detail the components, operation, and interconnection of the system. A more detailed description of operation may be found in the operation and maintenance manual for each individual inverter design.

## 2.0 Inverter

Xantrex Technology manufactures a patented insulated gate bipolar transistor (IGBT) based power electronic inverter. There is presently over 2200 MW of installed capacity of Xantrex Technology inverters throughout the world in wind, solar photovoltaic, battery energy storage, industrial drive and stand-alone hybrid power system applications. The production and reliability history that has been established in this application is unique in the power conversion industry.

### 2.1 Inverter Hardware

The inverter is detailed on the attached block diagram at the end of this document. Descriptions of operation of the major components are as follow.

#### 2.1.1 Inverter Circuit and Capacitor Bank

The inverter matrix utilizes IGBT technology as the main power semiconductor-switching device. This technology exhibits both the high power levels and low conduction losses associated with bipolar devices, as well as the low switching losses and high switching frequencies associated with MOSFET devices. In addition, Xantrex Technology employs IPM (Intelligent Power Module) switching Technology. Together the IGBT and IPM offer protection logic for short circuit, over temperature, DC overvoltage and AC over/undervoltage conditions.

#### 2.1.2 Integrated Bus Board (PV5208 through PV20208)

The integrated bus board receives logic level timing signals from the digital signal processor (DSP) board and converts these signals to IGBT switching states. Additionally, the integrated bus board monitors the condition of the IGBTs and reports fault conditions to the DSP controller. The DSP is plugged directly into the integrated

bus board and is designed to the industry standard specification PC-104.

### 2.1.3 Digital Signal Processor (DSP) Board

The DSP controller board utilizes a digital signal processor integrated chip to implement control and system monitoring functions. The DSP software implements the peak power tracker function for optimizing the power delivery from the PV array.

The DSP commands the integrated bus board to issue the appropriate gating signal to the IGBTs, as determined from the digitized current and voltage waveforms at the inverter input and output, and by the control commands received through the operator interface. The DSP based control board communicates with the operator interface board via PC-104 bus.

### 2.1.4 AC Line Filter

The AC line filter removes harmonic currents at the utility power system interconnection. Due the high switching frequency and the pulse-width-modulation (PWM) technique used with the inverter, the filter is modest in size, and need only remove high frequency harmonic current components.

### 2.1.5 Operator Interface

There are three means of operator interface with the PV series inverter family. An optional configuration (standard configuration on the PV5208) consists of three LED lights and an on/off toggle switch located on the front door of the inverter. The LED lights indicate system status and detail any fault conditions. The two optional operator interfaces consist of a liquid crystal display and a graphical user interface (GUI) for use with an external computer. The on/off toggle switch is used to enable or disable inverter operation and clear fault conditions. It is included in all operator interface configurations.

The standard PV series configuration (PV10208 through PV30208) consists of an LCD display and an on/off toggle switch located on the front door of the inverter. It consists of a four-line text display, which continuously reports system status, AC power, DC voltage, DC current, as well as any fault conditions.

The optional GUI interface program may be used in conjunction with either the LED or LCD display configurations. The GUI interface allows access via an RS-232 cable to the inverter system status, inverter controls, expanded details of operation (line currents, line

voltages, frequency, etc.), and user adjustable system operation parameters. Contact Xantrex Technology for further information.

## 2.2 Power Quality

The state-of-the-art technology used in the Xantrex Technology inverter results in exceptional power quality. The use of IGBT devices allows for high switching frequencies. The combination of the high switching frequencies and AC line filter produces high fidelity waveforms which are well below the IEEE-519 recommended limits for total harmonic current distortion.

Unlike line-commutated inverters, the Xantrex Technology inverter allows power factor to be regulated precisely at unity, eliminating the need for external reactive power compensation.

## 2.3 Self-Protective Features

The inverter has many built-in protective features to prevent or limit damage to the photovoltaic system, the inverter, and the utility distribution system in the event of a component or system-level malfunction. These features provide for orderly system shut-down without the need for many external protective devices. Among the features are:

### 2.3.1 IGBT Device Protection

IGBTs are protected by DC overvoltage, overcurrent and overtemperature functions. Setpoints for these functions are fixed at the time of factory test, and can only be changed through the diagnostic port on the microprocessor controller inside the enclosure.

### 2.3.2 Utility Voltage and Frequency Monitoring and Protection

The DSP controller constantly monitors the stability of the utility voltage waveform. If the waveform degrades beyond allowable limits the inverter will stop processing power and disconnect from the utility. Once stable utility voltage is restored for five minutes, the DSP will automatically clear the fault and resume normal operation. Trip magnitudes and time delays are user settable through the operator interface.

### 2.3.3 Utility Islanding Protection

Detection of islanding from the utility grid is achieved via AC over/undervoltage and over/underfrequency detection functions as well as load destabilization algorithms in compliance with UL1741. Setpoints and time delays for some of these functions are field settable through the graphical operator interface program. Settings are password protected, requiring a certified technician to make any changes to factory defaults.

### 2.3.4 Additional Protection

- AC current unbalance detection to prevent single-phasing due to blown fuses
- DC ground fault detection and annunciation resulting in an orderly inverter shutdown.

### 2.3.5 Standards

The Trace family of photovoltaic inverters; PV5208 through PV20208 is in compliance with IEEE519 and IEEE929 utility standards, Underwriters Laboratories (UL1741) and the National Electric Code (NEC). The PV30208 is pending UL1741 certification, due July 2001. Our facility is registered by Underwriters Laboratories Inc. under the International Organization for Standardization ISO9000.

## 2.4 Environmental Considerations

The PV Series control hardware is housed in an outdoor rated NEMA4/3R polyester powder coated steel enclosure. The inverter may be manufactured to tolerate an outdoor, exposed environment. However, we recommend protected, indoor installation to maximize the lifetime of the inverter.

The PV Series should also be protected from harsh and corrosive environments. The allowable temperature range of operation is -20 to 50°C. The PV Series should be allowed a 15 minute warm up period prior to operations when powered up below 0°C.

## 2.5 Summary of PV Series Inverter Specifications:

|                              | <b>PV5208</b>  | <b>PV10208</b> | <b>PV15208</b> | <b>PV20208</b> | <b>PV30208</b> |
|------------------------------|--|----------------|----------------|----------------|----------------|
| <b>AC Line Interface</b>     |  |                |                |                |                |
| Continuous AC Output Power   | 5kW  | 10kW           | 15kW           | 20kW           | 30kW           |
| Full Load Efficiency         | Greater than 95% (see efficiency curve in section 8.0) |                |                |                |                |
| Nominal Line Frequency       | 50/60 Hz +/- 0.5Hz                                     |                |                |                |                |
| Nominal Line Voltage         | 208Vac -12%, +10% (per UL1741 & IEEE929)               |                |                |                |                |
| Continuous AC Output Current | 15.2Aac  | 30.5Aac        | 45.8Aac        | 61.0Aac        | 91.6Aac        |

|   | PV5208  | PV10208               | PV15208     | PV20208 | PV30208         |
|---|---|-----------------------|-------------|---------|-----------------|
| Power Factor  | Unity +/-0.02   |                       |             |         |                 |
| AC Current Distortion   | Less than 5% lthd, 3% lhd   |                       |             |         |                 |
| PV Array Configuration  | Monopole-Negative Grounded, Bipolar-Neutral Grounded, or Floated  |                       |             |         |                 |
| Maximum PV Array Voltage  | 600Vdc  |                       |             |         |                 |
| PV Peak Power Point Window  | 300* - 600Vdc   |                       |             |         |                 |
| *Minimum PV Peak Power Voltage                                      | 280 – 330Vdc dependant upon actual AC line voltage at inverter  |                       |             |         |                 |
| PV Array Maximum Input Current                                      | 17.8Adc   | 35.7Adc               | 53.6Adc     | 71.4Adc | 107.1Adc        |
| PV Ripple Current   | Less than 5%  |                       |             |         |                 |
| <b>Operator Interface</b>   |   |                       |             |         |                 |
| Standard Interface  | LED   | LCD                   | LCD         | LCD     | LCD             |
| LED Display   | Three LED Display: Green, Yellow, and Red   |                       |             |         |                 |
| LCD Display   | 4 Line Liquid Crystal Display   |                       |             |         |                 |
| LDC Display Parameters  | Target State<br>Operating State<br>AC Output Power (kW)<br>DC Voltage<br>Fault Descriptions   |                       |             |         |                 |
| Graphical User Interface (optional)<br>Operating Display Parameters | Operating State<br>AC Power (kW)<br>AC Line Voltages (Line-to-Line)<br>AC Output Phase Currents<br>PV DC Voltage<br>PV DC Reference Voltage<br>Ground Fault Current<br>Fault Codes and Descriptions<br>Protective Function Targets<br>Inverter Status |                       |             |         |                 |
| Serial Interface  | RS-232 DB9 Female Serial Cable to Computer COM1 Port  |                       |             |         |                 |
| User Settable Parameters  | PV Start Voltage<br>Peak Power Point Reference Voltage<br>PV Shutdown Power<br>Peak Power Tracker Perturbation Step<br>Ground Current Fault Threshold<br>Utility Voltage & Frequency Trip Points*<br>Utility Voltage & Frequency Time Delays*         |                       |             |         |                 |
| <b>Protective Functions</b>   |   |                       |             |         |                 |
| Active Protection Features  | AC Line Over/Under Voltage<br>DC Over Voltage<br>AC Line AC Over Current<br>Inverter Over Temperature<br>Island Detection/Prevention<br>AC Line Over/Under Frequency  |                       |             |         |                 |
| <b>Environmental</b>  |   |                       |             |         |                 |
| Temperature   | -20°C to +50°C  |                       |             |         |                 |
| Relative Humidity   | 90% Non-Condensing  |                       |             |         |                 |
| Elevation   | Derated above 3300 feet   |                       |             |         |                 |
| Enclosure Rating  | NEMA4 Outdoor   |                       |             |         | NEMA3R/4        |
| Cooling   | Natural   | Forced Air Convection |             |         |                 |
| Dimensions  | 20Hx16Wx13<br>D   | 26Hx16Wx12<br>D       | 29Hx24Wx16D |         | 52Hx26Wx19<br>D |
| Weight (Approximate)  | 75lbs   | 90lbs                 | 175lbs      |         | 375lbs          |
| UL1741 Certification  | Yes   |                       |             |         | Pending         |

|                       | PV5208                | PV10208 | PV15208 | PV20208 | PV30208 |
|-----------------------|-----------------------|---------|---------|---------|---------|
| Regulatory Compliance | NEC, IEEE519, IEEE929 |         |         |         |         |

\*May only be adjusted by qualified personnel, with agreement from the local utility

### 3.0 Control and Instrumentation

#### 3.1 Operating Mode

The converter utilizes Xantrex Technology unique power tracking algorithm to operate in a power maximization mode to ensure there is sufficient irradiance at all times to overcome inverter losses. Inverter start-up occurs when the PV open circuit DC input voltage rises above the user settable wake-up voltage. The inverter transitions back to the idle state for nightly shutdown when losses exceed input power for user settable time period.

The power-tracking algorithm includes the intelligence and rapid response time necessary to limit the DC input power to its design value. Cloud enhancement effects are handled within the algorithm by moving off of the maximum power point and remaining at the design rated power level. This eliminates the need for the source circuit dumping contactors, crowbar circuits, and similar unreliable schemes used to protect other types of inverters.

#### 3.2 Local Control

Local control is implemented through an on/off toggle switch located on the front door of the inverter. The switch enables or disables inverter operation and is used to clear fault conditions.

#### 3.3 Local Instrumentation (Optional)

The following real-time system status parameters are available through the LCD operator interface:

- AC Voltage
- AC Output Current
- PV Voltage
- Converter Status and Alarm Descriptions

#### 3.4 Remote Control and Instrumentation (Optional)

The DSP control board has provisions for installation of an RS-232 communication link for interface to an external computer and graphical user interface program. All local interface parameters, as well as additional operating parameters, status indicators, protective function targets, and user-adjustable parameters are accessible through from the GUI interface.



### 3.5 User Settable Parameters

The PV series operating parameters are factory set to be in compliance with UL1741 and IEEE929, as well as to provide stable efficient operation with most PV installations. Parameters may be adjusted via the optional graphical user interface. Some parameters related to utility protection functions may only be adjusted by qualified personnel, with agreement from the local utility.

### 4.0 Isolation Transformer (Required: Available from Xantrex Technology)

An isolation transformer is required if local regulations require grounding of the PV system, or if the utility voltage is not 208 VAC. Due to the low level of harmonic distortion produced by the converter, a general purpose dry type transformer is suitable for this application. The transformer must have a 208 volt delta secondary winding, a primary winding rated to match the interconnect voltage, and any local utility interconnection requirements. An optional enclosed, molded-case, thermal-magnetic circuit breaker may be provided for transformer over-current protection. This breaker may serve as the utility disconnect, eliminating the requirement for the AC disconnect switch described above.

Isolation transformers are available from Xantrex Technology. We commonly provide transformers with 208V delta (inverter side) to WYE rated at the utility interconnection voltage, 97-98% efficient, housed in a NEMA3R enclosure. Contact Xantrex Technology for other available transformer configurations.

| PV Series | Inverter Wt. (lbs.) | Isolation Transformer (Inches, typical) | Mounting | Transformer Wt. (lbs.) |
|-----------|---------------------|---|----------|------------------------|
| PV5208    | 75                  | 19Hx16Wx9D                              | Wall     | 130                    |
| PV10208   | 90                  | 24H x 22.5W x 22D                       | Floor    | 220                    |
| PV15208   | 115                 | 24H x 22.5W x 22D                       | Floor    | 300                    |
| PV20208   | 180                 | 24H x 22.5W x 22D                       | Floor    | 350                    |
| PV30208   | 375                 | 30H x 20W x 24D                         | Floor    | 350                    |

### 5.0 AC and DC Disconnect Switches (Optional)

Disconnect switches for isolating the inverter from AC and DC power sources are available from Xantrex Technology. These switches are rated for use with the inverter and PV applications. Fusible and non-fusible models are available. All Xantrex Technology supplied switches are NEMA3R outdoor rated, pad-lockable, and equipped with external operator handles. Contact Xantrex Technology for further information.

### 6.0 Photovoltaic Combiner Boxes (Optional)

Interface enclosures for paralleling multiple PV string circuits are available from Xantrex Technology. These devices have been listed under UL1741 and are

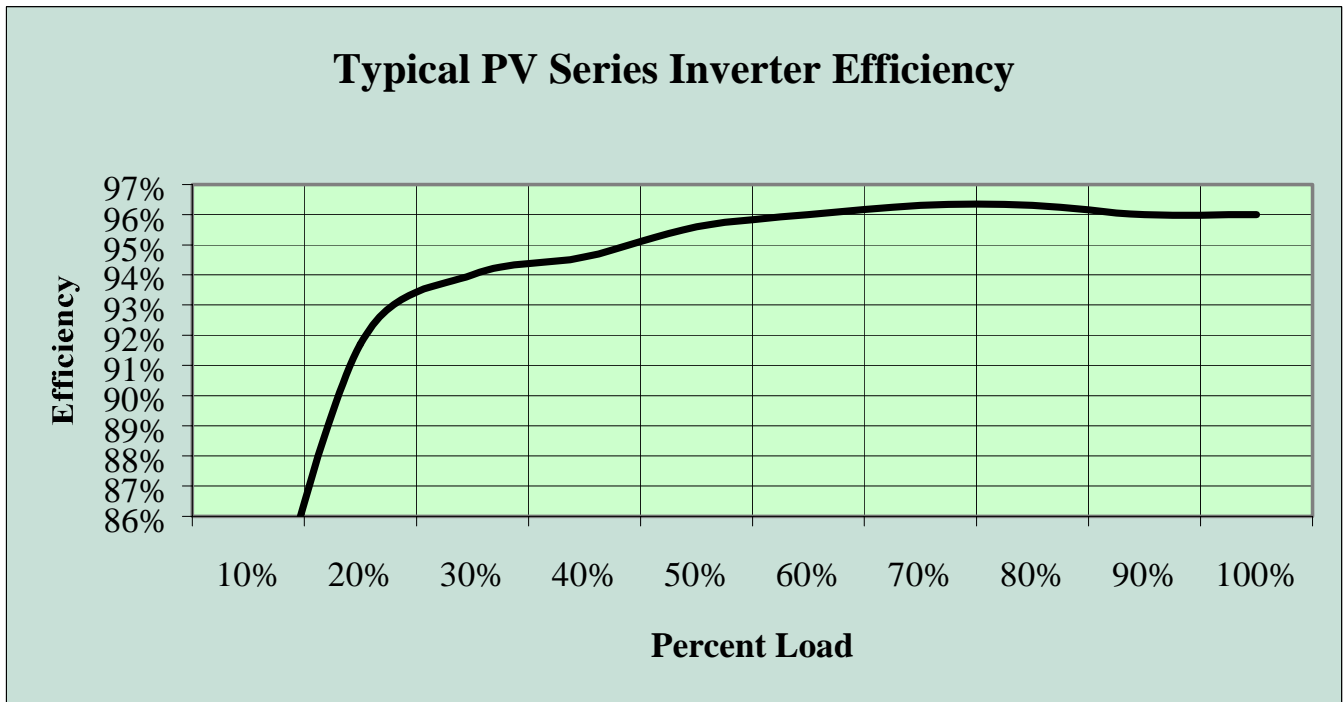


NEMA3R outdoor rated. They are capable of paralleling up to 10 or 12 individual PV source circuits. Circuits may be protected with up to a 20 ampere, 600Vdc fuse. Diode equipped reverse-current protection models are also available. The 12 circuit model is equipped with 'touch safe' break apart fuse holders for additional personnel safety and protection. Contact Xantrex Technology for further information.

### 7.0 Maintenance Requirements

Routine maintenance requirements are minimal, consisting only of periodic inspection of the cooling fans, enclosure seals, and electrical connections.

### 8.0 Efficiency Graph

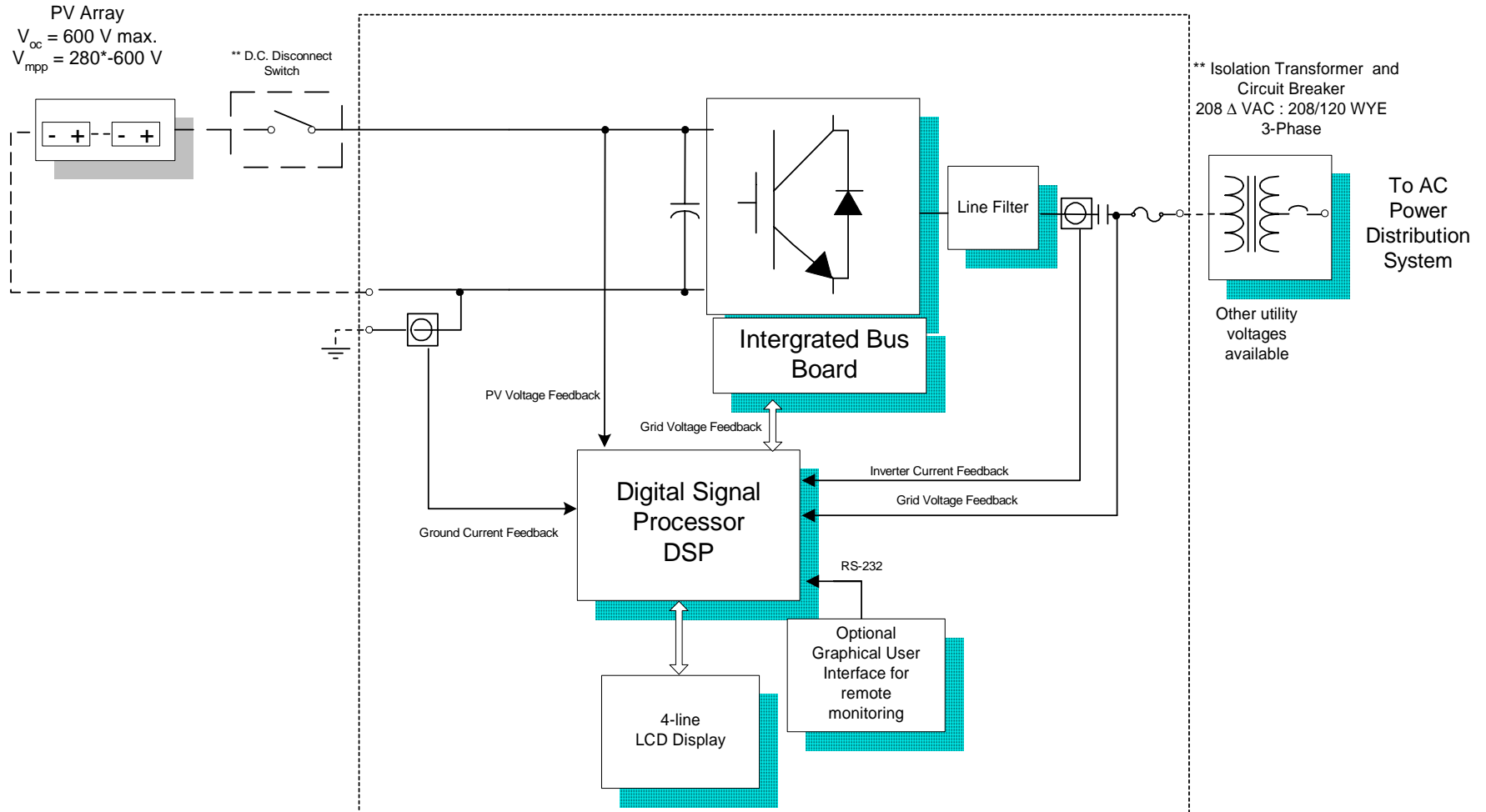


### 9.0 Attachment

Inverter Schematic Block Diagram

# Power Conversion System for Grid-Tied Photovoltaic Application

## Electrical and Control Block Diagram Grid Interface Inverter



### Notes:

\* Minimum peak power tracking voltage dependent upon actual line voltage seen at inverter input terminals.

\*\* The Isolation transformer DC disconnect switch, DC combiner box, laptop computer and AC circuit breaker (not shown) may be customer supplied or are available from Xantrex Technology.