SPICER CONSULTING

SYSTEM SC26

SC26 Magnetic Field Cancelling System

- **Makes the ambient magnetic field "OK" for electron beam tools in 300 mm wafer fabs**
- **Real time, wideband cancelling from DC to > 9 kHz fields**
- **Adapts to field amplitude and frequency changes within 10 µs**
- **Touch screen intelligent user interface with automatic setup and DC reset**
- **Simultaneous AC & DC field display with choice of Tesla or Gauss units**
- **Mixes dual sensors to create virtual sensor "inside" the EM column**
- **Built-in test field generator**
- **Ethernet and USB ports for remote operation and monitoring**

Overview

Wafer transport robots in 300mm wafer fabs. make 9 kHz fields that limit the performance of electron beam tools and are a barrier to achieving the next semiconductor CD node.

The SC26 is a wide bandwidth system that can cancel magnetic fields from DC to above 9 kHz.

To achieve its wide bandwidth, the SC26 uses low inductance field cancelling cables, installed in the electron beam tool enclosure (Fig. 4).

The SC26 has inputs for two 200 kHz AC field sensors (blue) that it can mix to optimise the electron beam tool performance. These provide useful cancelling down to 10 Hz.

Cancelling can be extended down to DC by adding a "Sensor SC24/DC+AC" and a sensor combiner for each input channel used.

The SC26 cannot be used with larger cables in a "room" installation like our SC24 system which operates at lower frequencies.

Ref: www.spicerconsulting.com/products

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Product Description

The SC26 is a fourth generation Magnetic Field Cancelling System that has been optimised to cancel the high frequency fields, typically at 9kHz, from robotic wafer transports in 300mm wafer fabs.

The SC26 is an enhanced replacement for the SC20Fast system, which has an installed base of over 200 units in wafer fabs world wide.

The principle of operation of the SC26 is similar to our other field cancelling systems, as on our website www.spicerconsulting.com. The field cancelling method is wideband analog negative feedback. An embedded microcomputer controls the system and digitises the fields for measurement but is not within the feedback loop.

The reference SC26 installation in an Electron Beam tool enclosure is shown in Fig. 4. The control unit is not shown. The field cancelling cables are shown in red, green and blue. This reference installation is used to specify the SC26 system performance.

The 200kHz "Sensor SC26/AC" (Fig. 6) measures the field, the control unit processes and filters the measurements and drives currents through the cables with the correct amplitude and phase to null the measured field.

"Sensor SC26/AC" is required for operation of the SC26 system. The SC26 control unit has inputs for two sensors. It will work with one or two. When it detects sensors in both inputs the SC26 enables the mixer function.

To get cancelling of DC fields, it is necessary to add a "Sensor SC24/DC+AC" to each used input through a Sensor Combiner unit. The SC26 will then enable DC cancelling and the DC field display on the touch screen. The DC cancelling option is complicated but sometimes necessary.

The SC26 does not cancel the field everywhere inside the electron beam tool enclosure. It creates a region around the magnetic field sensors where the field is much reduced. The volume of this region depends on the uniformity of the ambient field, the design of the field cables and the amount the field is distorted by the metal structure of the electron beam tool.

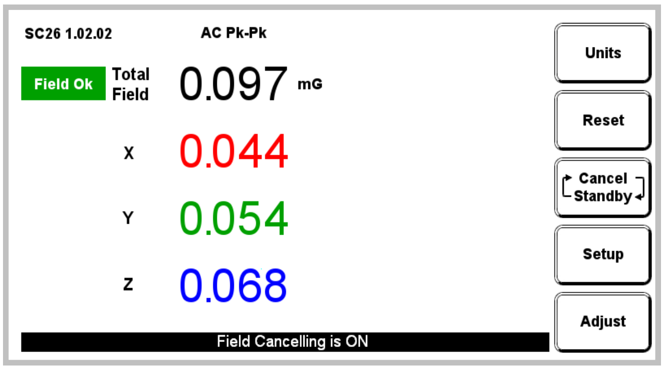


Fig. 1. Typical touch screen display

The SC26 user interface is a touch screen LCD display panel shown in Fig. 1 above. This is a typical display for an SC26 with one or two "Sensor SC26/AC" when the system is cancelling and the field is OK. The DC field values are not displayed because no DC sensors are installed.

When DC sensors are also installed, the display appears as in Fig. 2

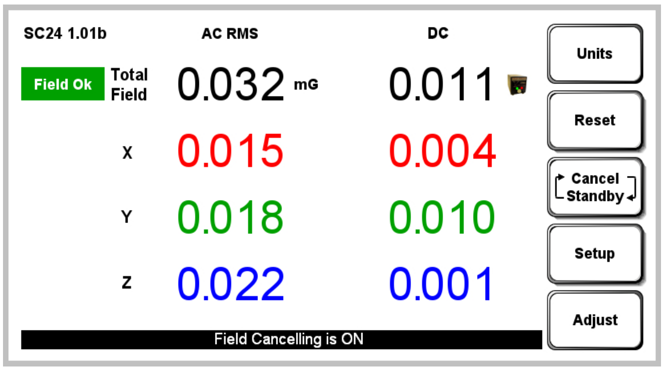


Fig. 2. Typical touch screen display with DC sensors

The five buttons control operation of the system.

The "Units" button calls up the units sub menu to select RMS or pk-pk, Tesla or Gauss units. The choice of units has no effect on cancelling.

The "Reset" button clears the "trip" indicators and resets the "zero field" operating point of the DC sensors.

The "Cancel/Standby" button turns cancelling on and off.

Magnetic field amplitudes are displayed with 100pT (1.0 µGauss) resolution. The DC field amplitudes are only displayed for DC sensors.

The magnetic field amplitudes are continuously monitored and compared with preset trip levels to provide "Field OK" indication.

The SC26 has "one button" automatic setup. On setup it analyses the installation, reports installation problems and sets up the feedback loop gain and phase. All setup parameters are stored in non-volatile memory. On power loss and subsequent power up it re-tests the installation. If it find no changes it resumes operation in the pre-power loss state, otherwise it requests setup.

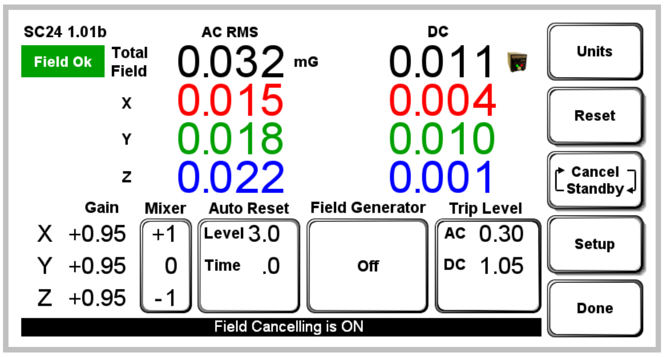


Fig. 3. Adjustment menu

The "Adjust" button enables entry to the adjustment menu (for expert users), typical display in Fig. 3. It also gives the option to "lock" the touch screen and reset the Ethernet password. When the screen is "locked" the five buttons are replaced by a new button that allows unlocking if pressed for five seconds.

The "Mixer", "Auto Reset", "Field Generator" and "Trip Level" touch buttons control the adjustments, described in the **Adjustment Details** section later.

Field cable installation

Most semiconductor electron beam tools are designed inside an enclosure supported by a steel frame.

To specify the installation of the SC26 system we have chosen typical enclosure dimensions of 1.75x1.75x 2.0 metres. (For actual tool dimensions, we consult with the tool manufacturer.)

Fig. 4 shows how the Helmholtz cables are installed in this enclosure. The 1 metre spacing between the cable loops is optimum to generate the best uniform field inside the enclosure. The loops are centred on the electron beam column.

The cables are deliberately not attached along the frame edges. Tool frames typically have welded or bolted construction which can create a closed conducting loop. Attaching the cables to this loop creates an air-cored transformer that can short out the cancelling field at frequencies above about 100Hz. See the SC26 user manual for details of this effect

Only cables supplied by Spicer Consulting for the SC26 can be used. The cables are shielded and have 2 cores. They are 3.0mm diameter and typically installed in 12.5 mm diameter plastic conduits for protection. The arrow labels on the cables must be installed in the direction shown.

The cables have nine pin D type connectors that plug together to form the two Helmholtz loops in Fig. 4 and the single loops in Fig. 5. A 2 core shielded cable runs from the loops to the SC26 control unit.

Custom cables with in-line connectors that will fit though the plastic conduit can be supplied for ease of installation and service of the tool.

Fig. 5 shows a simpler minimal installation with single loop cables that has been used with the previous SC20Fast system. The field uniformity is poor but useful improvement in the tool performance can often be obtained by careful choice of the sensor position. The cables are shielded and have 4 cores. They are 5.0mm diameter.

Sensor installation

The two sensor inputs are on the back of the SC26 Control Unit (CU).

There are only four allowed sensor configurations

"Sencon 1"

1 x Sensor SC26/AC, in one of the CU sensor inputs

"Sencon 2"

2 x Sensor SC26/AC, one in each CU sensor input

"Sencon 3"

1 x Sensor SC26/AC, 1 x Sensor SC24/DC+AC
1 x SC26 Sensor Combiner.
The sensors plug into the Combiner which plugs into one of the SC26 CU sensor inputs

"Sencon 4"

2 x Sensor SC26/AC, 2 x Sensor SC24/DC+AC
2 x SC26 Sensor Combiner.
The sensors plug into the 2 Combiners which plug into the two SC26 CU sensor inputs

(This is a double set of Sencon 3)

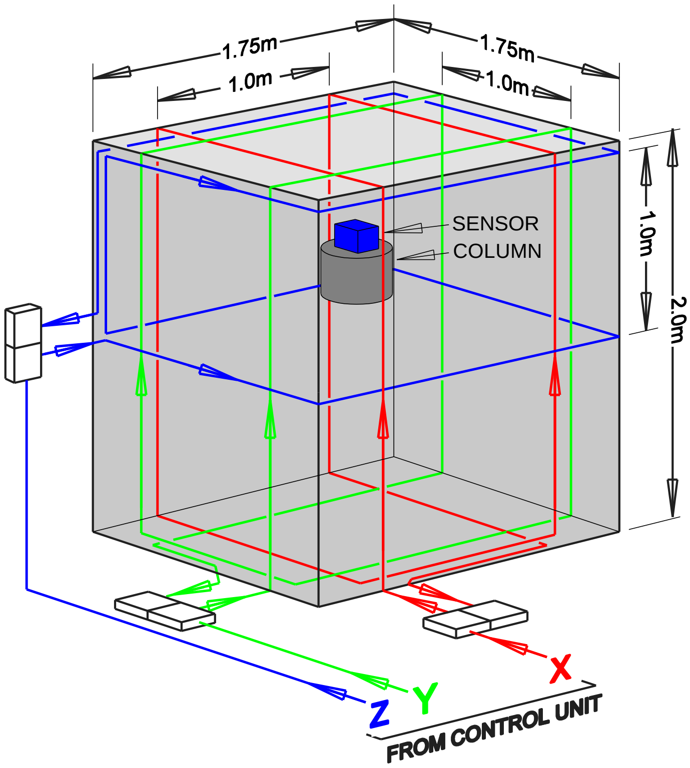


Fig. 4 Reference Installation

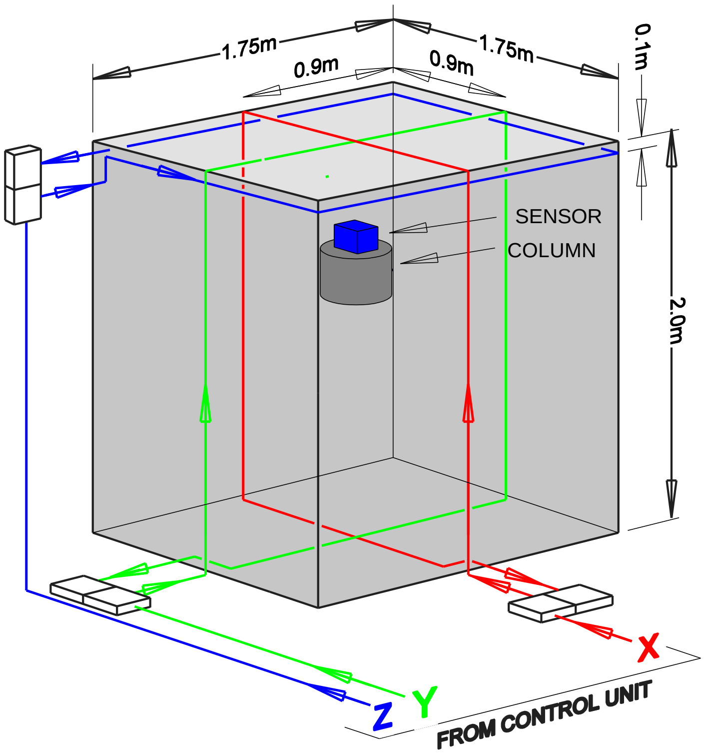


Fig. 5. Minimal Installation

Fig.6
Sensor SC26/AC

Fig.7
Sensor SC24/DC+AC

Fig. 8
SC26 Sensor Combiner

"Sencon 1"

This is the minimal configuration. The sensor is shown placed on top of the tool column in Figs 4 & 5. The optimum sensor position is determined by experiment by observing the tool image improvement.

The SC26 cancels the field at the sensor position. The field at other locations in the tool is the difference between the ambient field and the field made by the cancelling cables at that location.

In wafer fabs the ambient magnetic fields have large gradients. The source of the 9 kHz fields from the wafer transport robots is in the clean room ceiling above the tool. The source of the 50/60Hz fields from the clean room wiring is usually under the floor below the tool.

The optimum sensor position for 9 kHz cancelling may be different to the optimum position for 50/60 Hz cancelling.
The perfect sensor position would be inside the tool column which is impossible .

"Sencon 2"

This configuration enables the SC26 mixer function to create a virtual sensor "inside" the tool column.

The sensors are placed either side of the tool column and the SC26 mixer is used to tune the image improvement.

Some experiment is still required to find the optimum sensor positions. The inside of the tool is usually crowded.

The optimum sensor positions for 9kHz and 50/60 Hz cancelling may still be different.

"Sencon 3"

This configuration provides DC field cancelling and more flexible 50/60Hz cancelling. The SC26 mixer function is disabled.

The optimum sensor positions are still determined by experiment observing the image improvement.

Now, the 9kHz field is cancelled at the Sensor SC26/AC position and the DC & 50/60 Hz fields at the Sensor SC24/DC+AC position. The sensors must be oriented in the same direction but can be in different positions.

This configuration can be very useful when there are bad 50/60Hz fields.

"Sensor SC24/DC+AC" contains small Helmholtz coils that surround its field sensing elements. They are used to offset the DC component of the ambient field including the earths field. At reset, the microcomputer in the sensor adjusts and remembers the currents in the coils to set the X, Y, Z sensor outputs to zero. The reset process takes 1 second. The sensor must be reset if it is moved.

The electron beam tool may make large DC fields during its operation, for example when loading wafers. These fields may overload the field cancelling system. The SC26 can detect the overload and automatically reset the sensor outputs.

"Sencon 4"

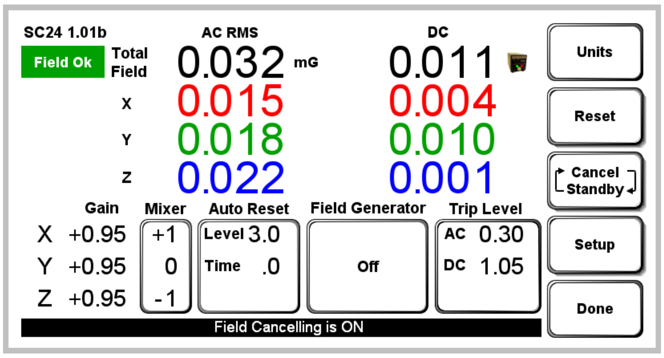
This configuration is the most flexible and the most powerful but also the most complicated and most expensive.

All four sensors must be oriented in the same direction but can be in different positions. The inside of the tool may be overcrowded.

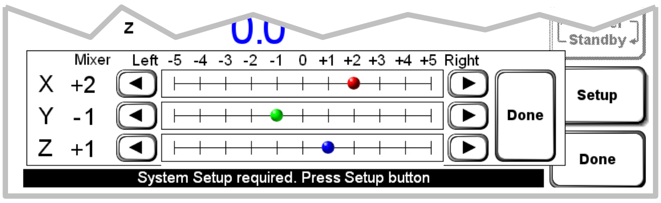
The SC26 mixer is enabled like in Sencon 2. The mixer acts on the combined signal from both types of sensors. There is no independent control.

Positioning the two Sensor SC26/AC is the same as in Sencon 2. After the mixer has been used to tune 9 kHz cancelling the optimum positions for the two Sensors SC24/DC+AC are found by experiment. They must be reset each time they are moved.

Adjustment details (Ref. Fig. 3)



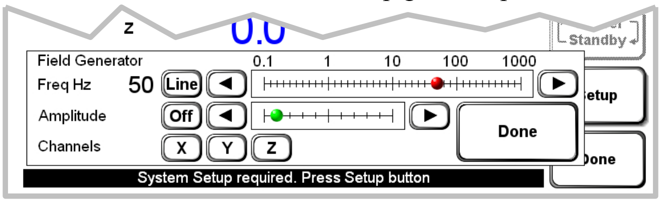
"Setup" automatically sets the feedback loop gains and phases. The gain values are displayed for reference. There is no manual adjustment.



The “Mixer” button opens a sub-screen with sliders to adjust the mixers, shown above. Run “setup” after adjusting the mixers (recommended).

The “Trip Level” button enables trip setting adjustment between 10nT and 200nT. The default trip levels are 25nT RMS (AC) and 100nT DC. The trip level has no effect on cancelling.

The SC26 has a built-in field generator that makes test fields using the cancelling cables. It uses the field generator during “setup” to measure the strength of the cancelling cables and determine the correct loop gain and phase.



The field generator can be used to make fields and test the sensitivity of the electron beam tool to those fields. The fields can be sine wave at line frequency or square wave at the frequency selected using the sliders below. Square waves are low pass filtered at 11 kHz. The test field can be connected to the selected axes.

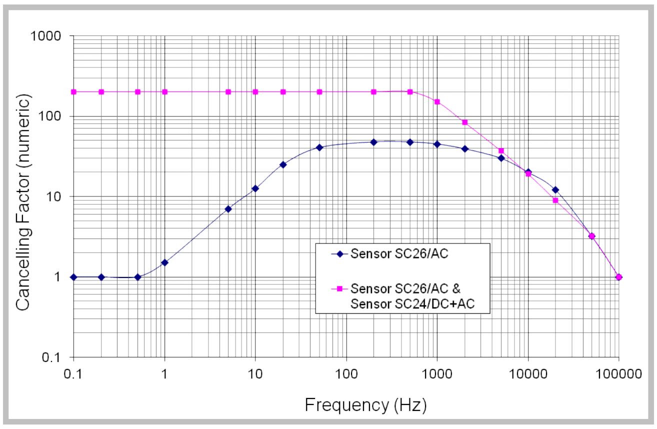
Outside the adjustment screen the field generator is set to OFF. Inside the adjustment screen, it is possible to have field generation and field cancelling at the same time (for experts only).

The “Auto Reset” button enables and disables auto reset and sets its sensitivity. When enabled, a small sensor icon appears on the main display (near the “units” button, Fig 2.)

Auto reset only happens when the SC26 is cancelling. It is triggered from the DC field level, which is usually near zero because the DC cancelling factor is large. During overload, the measured field rises abruptly, triggering auto reset.

To prevent nuisance resets “Auto Reset” delays before it resets the DC sensor. The overload field and time delay can be set. The defaults are 500nT and 5 seconds.

Cancelling Factor



The “cancelling factor” is the ratio of the ambient field to the cancelled field. A graph of cancelling factor vs. frequency is above.

Networking

The SC26 has USB and Ethernet ports for communication with the customer’s computer network.

The Spicer Consulting “SC24 Monitor” software package for installation on the customer’s computer network is compatible with System SC26.

You can use the “SC24 Monitor” to:

- Remotely view the SC26 front panel display.
- Remotely control the SC26 using the touch screen buttons
- Display a chart of the SC26 magnetic field readings.
- Export data to the SCPlot program or a spreadsheet.
- Log the SC26 magnetic field readings to a text file for subsequent viewing in SCPlot or a spreadsheet.
- Send email alerts under the following conditions:
  - SC26 goes off line
  - Field is not OK
  - X, Y or Z field components trip
  - SC26 screen displays a message

Specifications

UNITS	mG, nT, µT, selectable
FIELD CANCELLING	
Co-ordinates	X, Y, Z rectangular Cartesian
Components cancelled	X, Y, Z fields
Dynamic range [NOTE 1]	5 µT pk-pk (Reference Installation Fig. 4)
1. With Sencon 1 or Sencon 2 (page 4)	
Field cancelling factor	20 x typ. at 9 kHz (Reference Installation Fig. 4)
	40 x typ. at 60 Hz (Reference Installation Fig. 4)
Cancelling noise limit (1 Hz to 10 kHz)	0.6 nT RMS total
2. With Sencon 3 or Sencon 4 (page 4)	
Ambient DC field limit	± 200 µT max
Field cancelling factor	20 x typ. at 9 kHz (Reference Installation Fig. 4)
	200 x typ. at 60 Hz & DC (Reference Installation Fig. 4)
Cancelling noise limit (DC to 10 kHz)	0.7 nT RMS total
DC drift [NOTE 3]	< 2 nT/ 24 hours
FIELD MEASUREMENT	
Types	Real time field
	AC RMS or pk-pk
	DC incremental (***Sencon 3 or Sencon 4***)
Display	
LCD touch screen	See product description
Sensor dynamic range	4.2 µT pk-pk
Accuracy [NOTE 2]	± 1.0 % of reading ± 1 nT
X, Y, Z real time field outputs	
Scaling	10 V/µT (1.0V/mG)
Range	± 12 Volts
Source resistance	2.7 kΩ
Connectors	3 x BNC
Bandwidth	25 Hz - 60 kHz (***Sencon 1 or Sencon 2***)
	DC - 60 kHz (***Sencon 3 or Sencon 4***)
TEST FIELD GENERATOR	
Sine wave	AC line frequency (50/60Hz) - line locked
Square wave	1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, 9000 Hz
POWER	120/240 V 50/60 Hz, 100 VA

Note 1: Dynamic range is stated at the nominal AC power input of 120 or 240 volts RMS
De-rate linearly for lower voltages

Note 2: Sensors are calibrated with 50 Hz, 1µT RMS square wave field.

Note 3. Drift (@23°C ±2°C, after 2 hour warm-up)