Particle Counter Manifold Systems
in the Semiconductor, HD and LCD Industries

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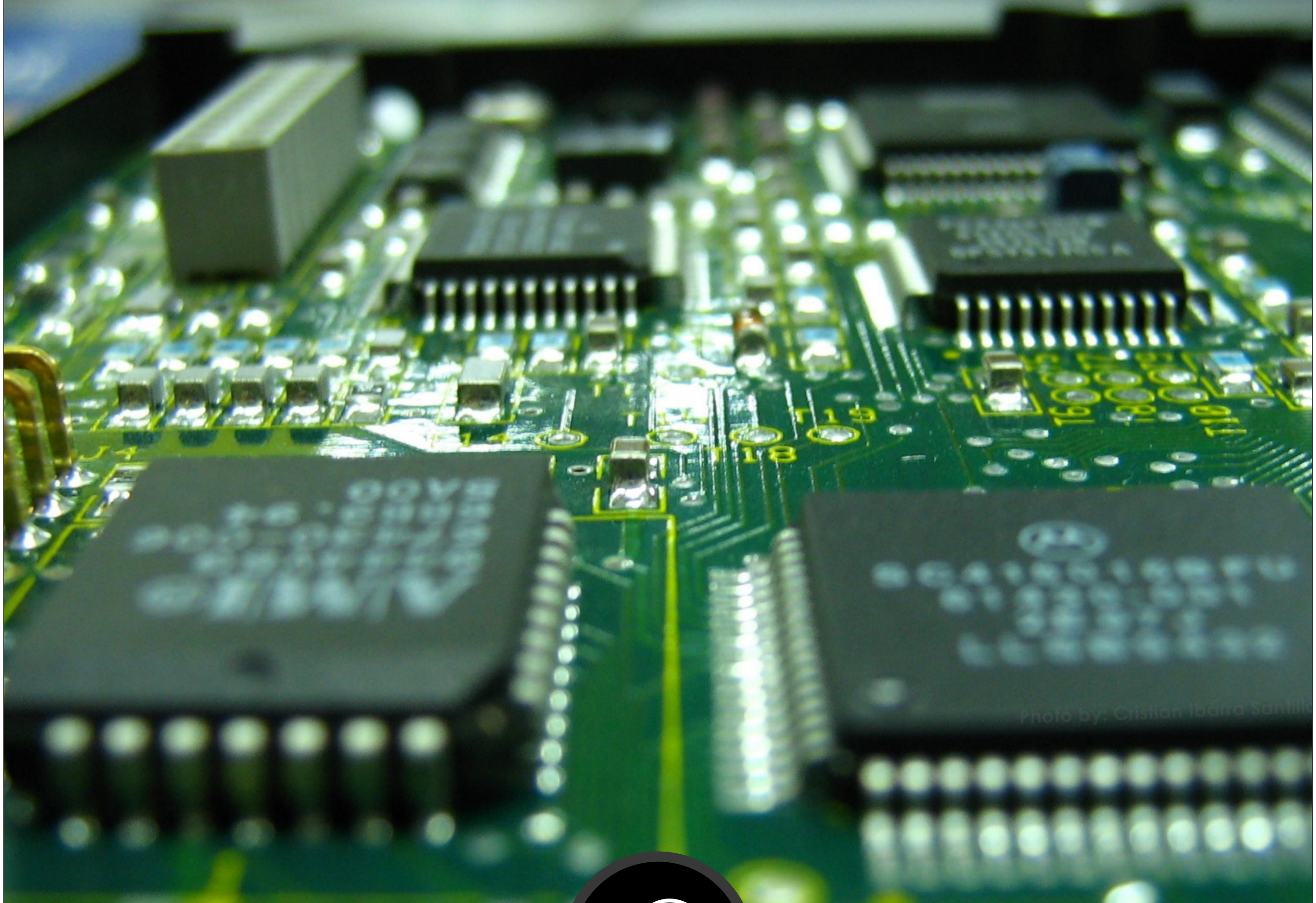


Overview

In this technical paper the term Semiconductor Industry encapsulates a wide variety of products which are made in cleanrooms which require cleanliness levels applicable to the type of products and devices manufactured requiring various node sizes down to 50nm.

These products include microelectronics, microcontrollers, sensors, actuators, digital signal processors, analog IC's, HDD controllers, Hard Disk Drives, controller chips, TFTs, OLED, QLED, Micro LED TV displays and monitors.

We will take a deep dive into Particle Manifold Systems and how they can be a great and economic alternative to Real Time Monitoring Systems that require remote particles counters at each monitoring location.

Particle monitoring has been integral to contamination control in semiconductor manufacturing. Optical particle counters measure particle levels in cleanroom air, as well as in gases, water, and chemicals used during manufacturing. As semiconductor production evolves, new demands are placed on optical particle counting technology and monitoring systems. This paper delves into the advantages of Particle Manifold Systems when looking for long term trends which can be utilized in product yield monitoring.

In modern semiconductor fabs, the manufacturing environment typically includes a central cleanroom along with smaller minienvironments dedicated to specific process tools. This setup offers a significant level of isolation, designed to effectively prevent contaminants from reaching the wafer processing areas. Strict cleanliness control in these environments is crucial to maintain high yield and efficiency in the manufacturing process.

Fabs generally adhere to the ISO 14644-1:2015 standard for periodic cleanliness certification.

This standard classifies a cleanroom based on the particle concentrations in a cubic meter sample of air using a particle counter. The old FS 209E standard is still ingrained in the minds of people working in cleanrooms as it was an easy reference to follow which provided quick clarification of a Cleanrooms cleanliness based on that room meeting Class 1,10,100,1000,10,000 or 100,000 At a 0.5-micron size with a sample volume of 1 cubic foot. The tables below shows the current ISO 14644-1:2015 standard and an alignment with this older Federal Standard which it superseded in 1999.

ISO Classification ISO14644-1:2015	FED-STD-209E Equivalent	EU GMP Classification	Limit (number per m^3)					
			≥0.1µm	≥0.2µm	≥0.3µm	≥0.5µm	≥1µm	≥5µm
ISO Class 1			10	2				
ISO Class 2			100	24	10	4		
ISO Class 3	Class 1		1000	237	102	35	8	
ISO Class 4	Class 10		10000	2370	1020	352	83	
ISO Class 5	Class 100	Grade A	100000	23700	10200	3520	832	29
ISO Class 6	Class 1000	Grade B	1000000	237000	102000	35200	8320	293
ISO Class 7	Class 10000	Grade C				352000	83200	2930
ISO Class 8	Class 100000	Grade D				3520000	832000	29300
ISO Class 9	Room Air					35200000	8320000	293000

ISO Classification ISO14644-1:2015	FED-STD-209E Equivalent	EU GMP Classification	Limit (number per ft^3) - Direct Conversion					
			≥0.1µm	≥0.2µm	≥0.3µm	≥0.5µm	≥1µm	≥5µm
ISO Class 1			0	0				
ISO Class 2			3	1	0			
ISO Class 3	Class 1		28	7	3	1	0	
ISO Class 4	Class 10		283	67	29	10	2	
ISO Class 5	Class 100	Grade A	2832	671	289	100	24	
ISO Class 6	Class 1000	Grade B	28317	6711	2888	1000	236	7
ISO Class 7	Class 10000	Grade C				10000	2356	70
ISO Class 8	Class 100000	Grade D				100000	23560	700
ISO Class 9	Room Air							

Contemporary semiconductor manufacturing facilities often utilize centralized particle monitoring systems to oversee particle levels within the process tool environments. These systems usually involve multiple remote particle counters that provide real-time sampling from various locations simultaneously, or a single particle counter that sequentially samples from different locations through a manifold. The particle sensitivity of the monitoring instruments is determined by the required cleanliness levels of the monitored environments.

All of these manufacturing processes in semiconductor cleanrooms require frequent monitoring of the environments. Airborne Particle Counters are one of the best ways to monitor manufacturing environments. In some applications manifold monitoring systems are used to frequently monitor multiple critical locations. Frequent monitoring of the air quality in critical locations provides trends to managers and process engineers and other cleanroom operators.

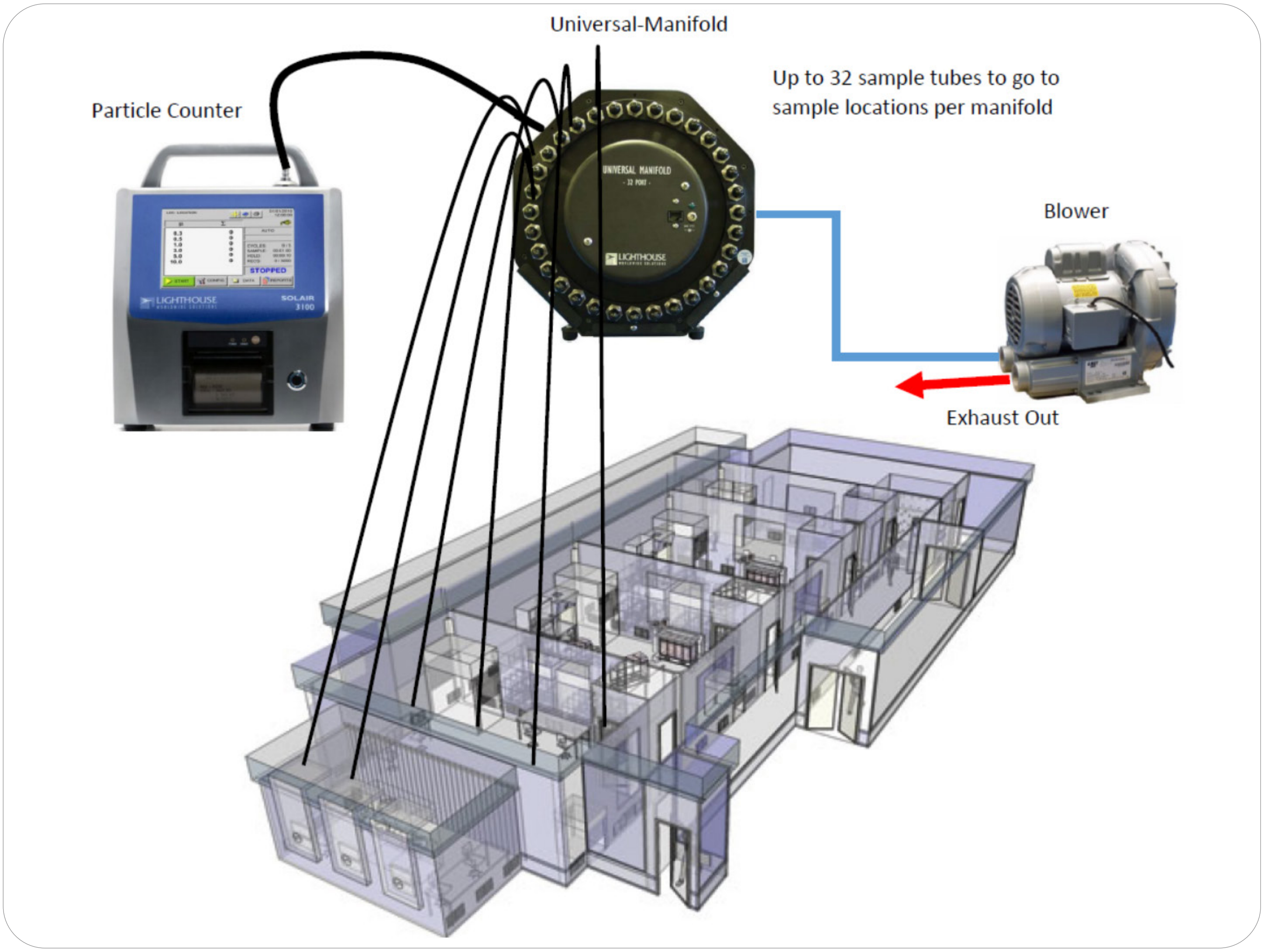
This frequent monitoring of the air quality provides useful feedback information on the performance of the cleanroom, the operators, equipment and other potentials of contamination sources. Correlations between product yields and contamination events can be determined with this trending data from the particle counts recorded by the manifold system and the real time software that connects to it.

What is a Manifold System?

A manifold system uses one particle counter and a mechanical system to align the sample inlet of the particle counter to the sample line to be sampled. Manifold systems come in different sizes based on the number of sampling locations required. Generally, the manifold systems can range from 5,10,20 to 32 sampling points.

Manifold systems can be connected to particle counters with 0.1cfm (2.83lpm) or 1.0cfm (28.3lpm) flowrates. The key concept of manifold systems is coverage, but the compromise is a manifold system is not a continuous system it is a sequential system.

Manifold systems reduce the need for multiple standalone particle counters, lowering equipment costs and simplifying maintenance. These systems are particularly effective in large-scale cleanrooms, where monitoring multiple points with individual counters would be impractical and expensive.



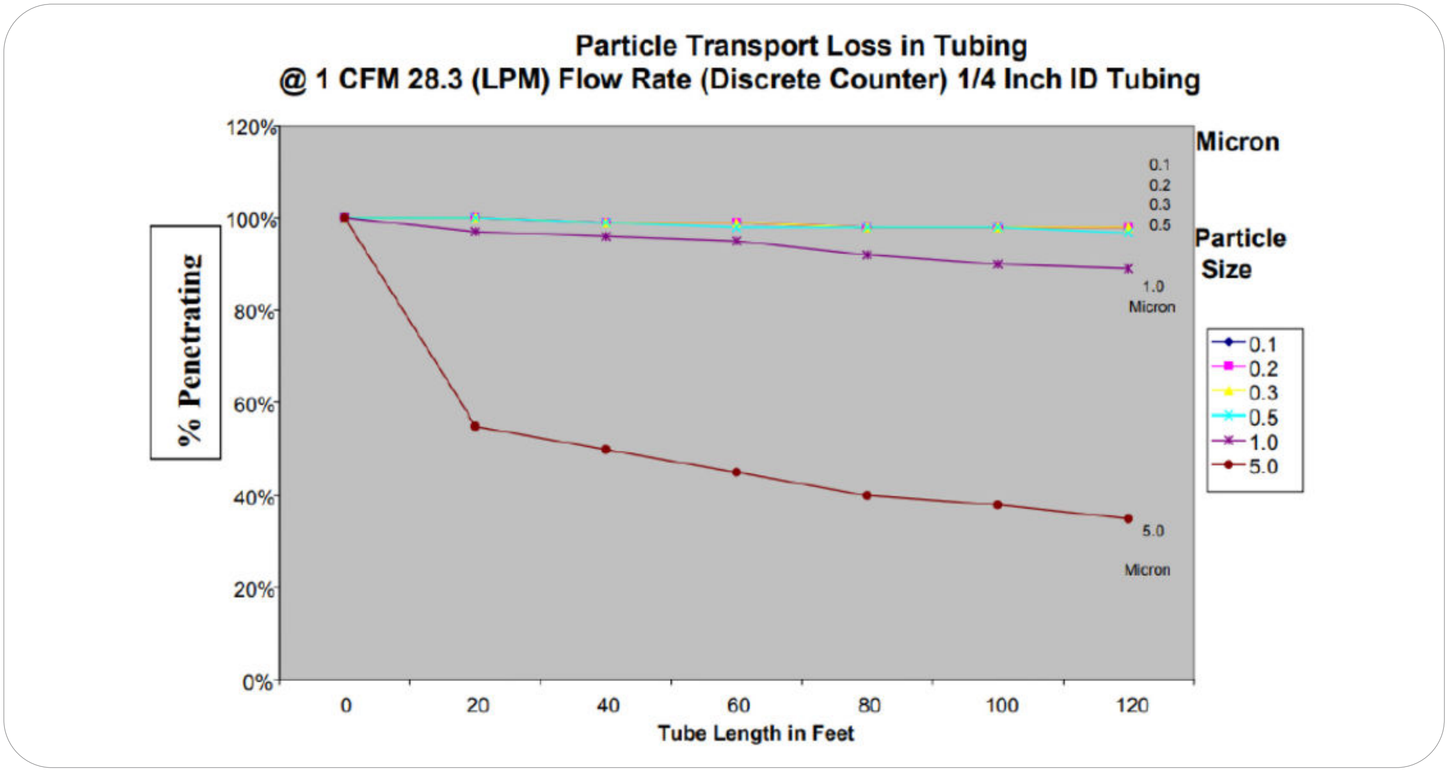
Example of a 32-port manifold system using a 1cfm Particle Counter

Sample Tubing Lengths

Manifold systems will have a limitation on the length of sampling tubing based on the ability of the blower to pull the samples through the tubing the system. Example illustrated above should not exceed 4,000 feet total length of all tubing runs and no single run should exceed 125 feet. There should be no kinks or sags in any tubing run and curves in the tubing should be gradual to enable a smooth transportation of particles along the tubing.

ASTM F50 standard outlines requirements for a tubing bend radius curvature which must not be below 15 centimeters to ensure smooth transitions and avoid particle loss in the tubing counter; this will prevent spurious counts.

Looking at the table below for particle transport loss in tubing it is recommended that manifold systems monitor particle sizes ≤0.5µm for trending purposes The losses for particle sizes of sizes equal or greater than 5.0µm and are too much an impact to ignore especially when applying the results to verify cleanroom certification validation. However, in semiconductor applications where 100nm particles are monitored the particle losses in that size range are acceptable. Especially since the objective of the particle monitoring is to develop a data trend for each specific location sampled.

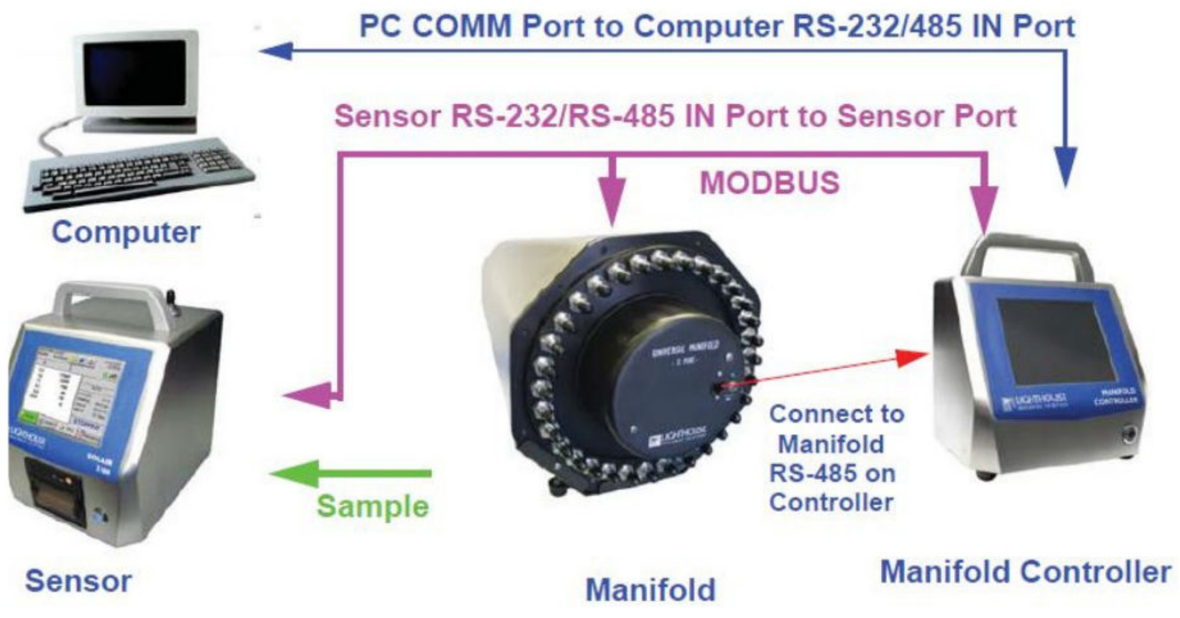


Example of particle losses in lengths of tubing based on particle size.

How do Manifold Systems Work?

A manifold system works by connecting sample tubing ports to a particle counter. This connection is done mechanically and automatically using a rotary system that aligns the sample tube port to the particle counter sample inlet. Samples can be configured based on the number of locations that the manifold supports (not all manifold port locations need to be used). Any unused ports in the manifold can be capped and those ports will not be programmed into the sample sequences. This method of monitoring is typically referred to as sequential monitoring.

The manifold system can sequentially sample from several points, ensuring thorough monitoring without the need for multiple standalone particle counters. This method helps in pinpointing specific sources of contamination by isolating the measurements from different locations.



Example of a 32 Port Particle Manifold System connected to trending monitoring software

Modern systems aim to control sampling locations down to a few particles at 0.1 μm. This necessitates manifolds designed for optimal flow efficiency, avoiding any right angles to enhance particle transportation along the sample tubing. Additionally, the design must prevent particle generation from internal mechanisms or cross-contamination.

Portable particle counters in these systems are versatile, used in various fab applications. They serve as portable devices in cleanroom monitoring plans or troubleshoot particles in specific process tools or areas. These counters also measure particles in gases both online and portably. Given their widespread use across the fab, these instruments need to be lightweight, battery-operated, and easy to use, even for personnel who handle them infrequently.

What are the basic installation parameters?

Certain conditions or parameters must be met or adhered to when designing manifold-based sampling networks. The following points are provided to assist during the design phase and to help troubleshoot failures. Keep in mind that the total number of active ports, tube length attached to those ports and the combined length of all tubes impacts the system performance. A change in any one factor affects the system.

A. **The maximum recommended total length of all tubing runs is 4,000 feet or 1216 meters.**

B. **Maximum recommended length for any run is 125 feet or 38 meters.**

C. **Shortest recommended length for any run is 10 feet or 3 meters.**

D. **All sample points should have isokinetic probe tips installed.**

E. **Flow at the manifold (through sample tubes) must be between 1.5 CFM (42.5 lpm) and 4 CFM (113.3 lpm).**

Note: Before attempting to balance a sampling network, it is strongly recommended that a check of the sample tube installation be made. Not doing so can invalidate testing and adjustments if sags, kinks or sharp angles were introduced during the installation of tubing runs.

Installation and Set Up

Let's look at the installation process of the Universal Manifold 32 port system that Lighthouse Worldwide Systems provides to the Semiconductor Industry and is widely used in many semiconductor applications worldwide.

The UM-II Manifold can be installed horizontally or vertically and should be located centrally to all tubing runs. This maintains a balance between sample ports that is beneficial to stable particle counts.

Warning:

Do not install the manifold near any wet processes. If a tubing run terminates near a wet bench or hazardous chemical vapor source, you must plumb the vacuum pump's exhaust to a scrubber. In addition, exposure of the sampling equipment to liquids or corrosive or reactive gasses may cause them to fail and void their warranties.

UM-11 Manifold

UM-II Manifold Specifications

Sample Ports	Up to 32 locations
Optional Manifold Blower (Vacuum Pump)	
Safety Provision:	Automatic pump shut-off
Power:	208, 418 VAC - Three Phase
Dimensions:	15" (w) x 20"(h) x 16.7"(d) [47x38x51cm^3]
Weight:	75 lbs (34 kg)
Flow Rate:	154 CFM
UM-II Manifold	
Flow Rate:	>1.5 CFM per port minimum
Particle Sample Tubing:	Particle transport tubing 1/2" OD, 3/8" ID (1.25 cm OD, 0.94 cm ID)
Fittings Provided:	32 barb fittings for 3/8" (0.94cm) ID sample tubing connection; 2 each push-in couplers for 1/2" OD particle counter sample tubing
Power:	24 VDC
Dimensions:	13.5"(w)x15.25"(h)x13.5"(d) [24x39x34 cm^3]
Weight:	13.5 lbs (6.1 kg)

Manifold Tubing

The tubing specified for the Manifold is Bevaline® hytrel-lined tubing. The maximum recommended length for any run is 125 ft. (38.1 m), the shortest length is 10 ft. (3 m) and the total for all runs is 4,000 feet (1216 m). To prevent large particle "dropout", it is critical to keep bend radii greater than 3 feet and avoid 90-degree, or tighter, tubing turns.

Do not "randomize" the port connections by mixing short tubing runs next to long runs randomly. Whenever possible, assign lengths from short to long back to short. Adjacent ports with radically different lengths attached require extended purge and hold cycles.

Suspended tubing MUST be supported over its entire length to prevent stretching, sagging or kinking and causing particulate dropouts. Keep tubing runs away from heat sources and high traffic areas and do not splice the tubes.

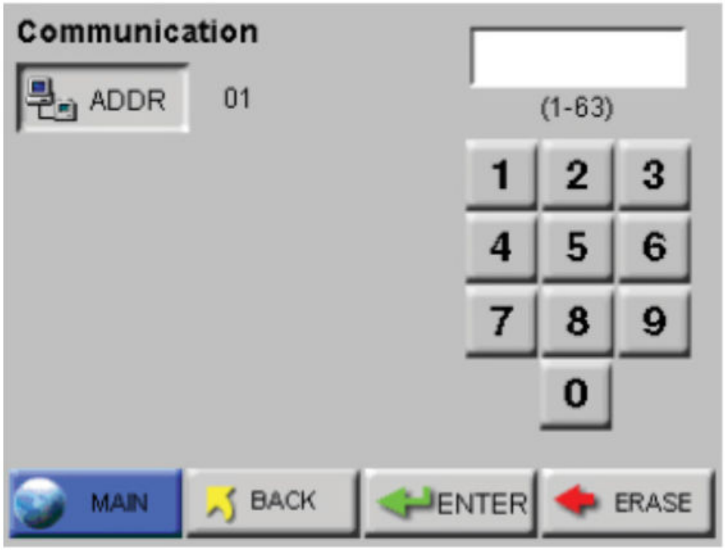
Manifold tubing and the Manifold itself are not recommended for wet processes nor should they be installed near wet processes. Do not allow fluid or chemicals to get inside the tubing, Manifold or Particle Counter. When preparing tubing for the Manifold, make sure the ends are cut perpendicular to the tubing. Perpendicular cuts will help to prevent leaks or particulate accumulation in the fittings.

Manifold Controller

Because the Manifold Controller communicates with the Particle Counter via RS-485, the Particle Counter address programmed into the Manifold Controller must match the Particle Counters COMM address as entered in "Set Particle Counter COMM Address" above.

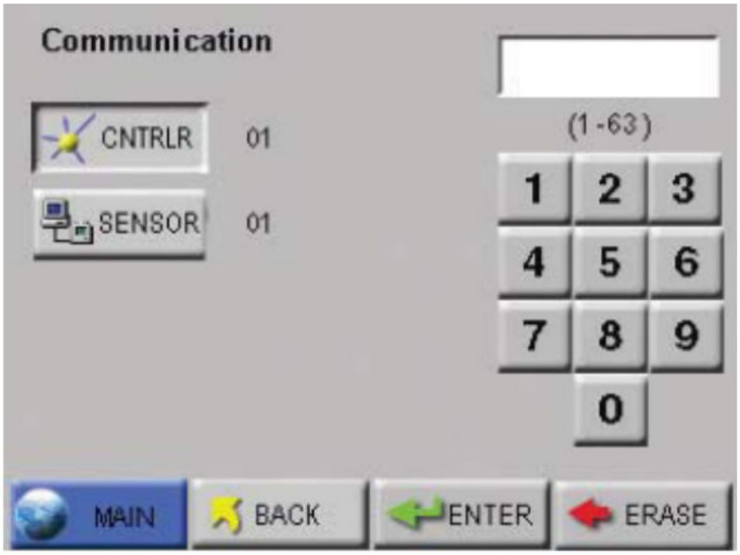
Connect the Manifold Controller to the Manifold by connecting a Cat5/6e cable to the connector labeled "Manifold" on the back of the Manifold Controller. Connect the other end of the cable to the connector on the front of the Manifold as shown below and on the interface screens of the Manifold Controller and the Particle Counter.

Connecting Manifold to Manifold Controller

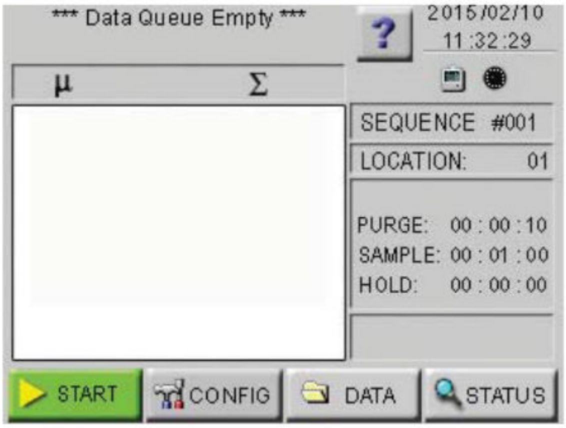


Particle Counter Communication interface

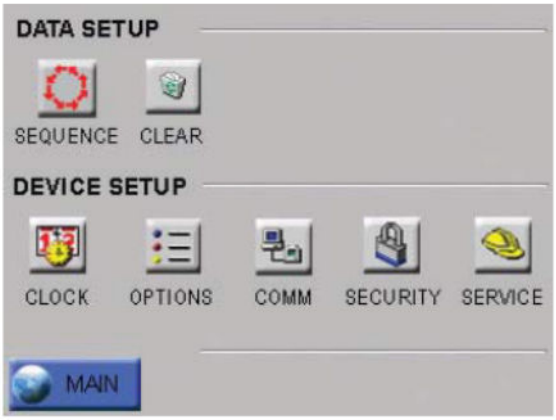
Connection of Particle Counter Sensor to the Manifold Controller



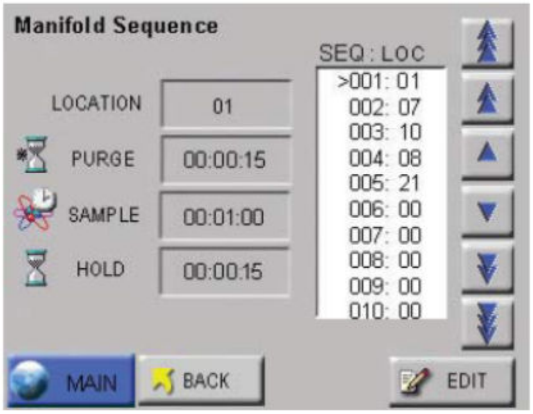
Manifold Controller communication to Particle Counter (Sensor)



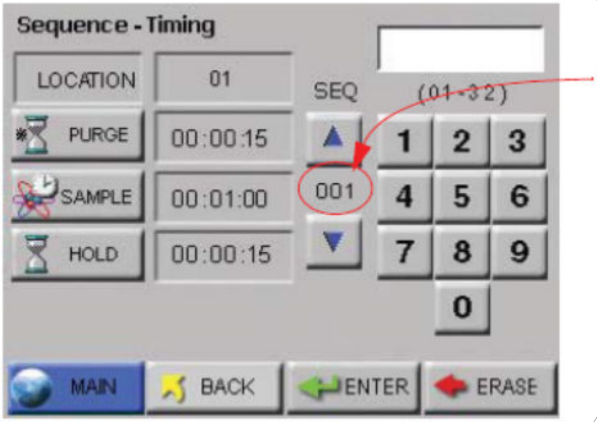
Manifold Controller Main Screen



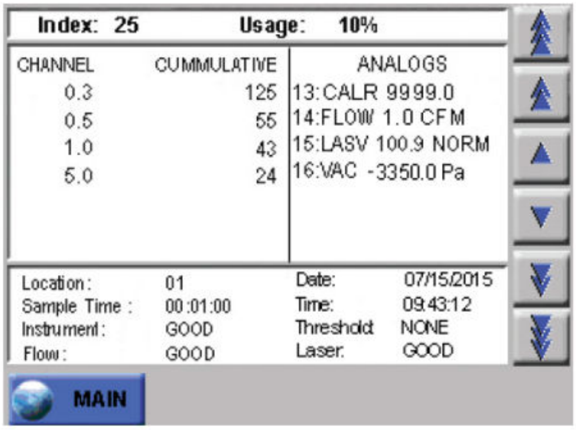
Manifold Controller Configuration Screen



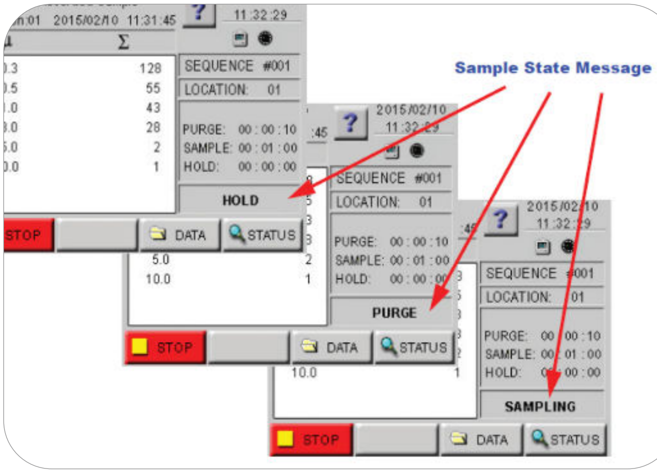
Manifold Sequence Configuration Screen



Manifold Controller Sequence Timing Screen



Example of Sample Location 01 and Particle Count Data as well as Other Parameters



Example of Sample States with Hold, Purge and Sampling status

Remote Mode

The Manifold Controller can be run from and controlled by the LMS Pro or Pharma facility system or by LMS Express software or connected to 3rd Party systems using MODBUS.

What Locations Should Be Monitored?

The selection of monitoring location points requires a good deal of knowledge on the semiconductor process. Here is a general overview of locations that should be monitored.

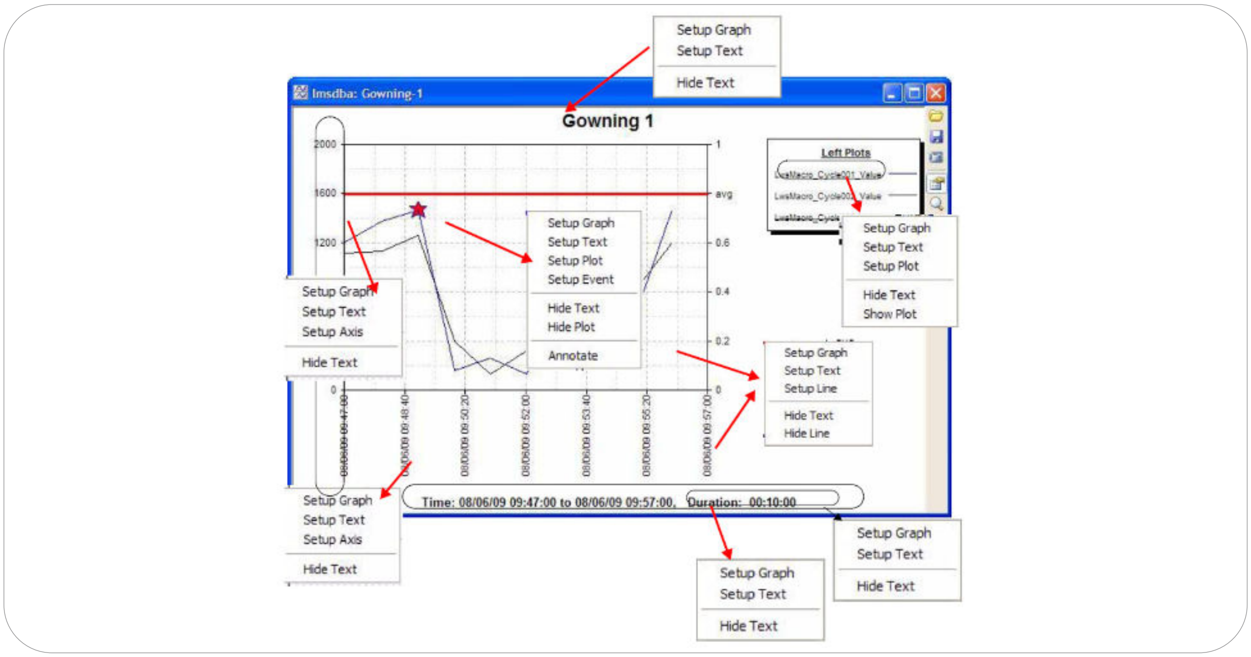
1. **Critical Process Areas**:
   Locations near the most sensitive process equipment where contamination can directly affect yield. This includes areas around photolithography tools, etching stations, and deposition chambers.
2. **Minienvironments and Isolated Chambers**:
   Enclosures within the cleanroom that house critical processes. Sampling within these minienvironments helps detect any breaches in isolation that could lead to contamination.
3. **Workstations and Operator Stations**:
   Areas where operators frequently interact with the tools and wafers. Monitoring these locations helps assess the impact of human activity on particle levels.
4. **Gowning and Entry Areas**:
   Zones where personnel enter the cleanroom. Sampling here helps monitor particles introduced through human movement and activities such as gowning and de-gowning.
5. **Air Showers and Pass-Throughs**:
   Transitional areas that help decontaminate personnel and materials before they enter the cleanroom. Ensuring these are functioning effectively is crucial for maintaining overall cleanliness.
6. **Return Air Ducts and HEPA Filters**:
   Locations where air is circulated and filtered. Monitoring these areas ensures that the air handling and filtration systems are working correctly to maintain the cleanroom's cleanliness.
7. **High Traffic Areas**:
   Paths and zones with frequent personnel and material movement. Sampling here helps monitor and control the spread of particles throughout the cleanroom.

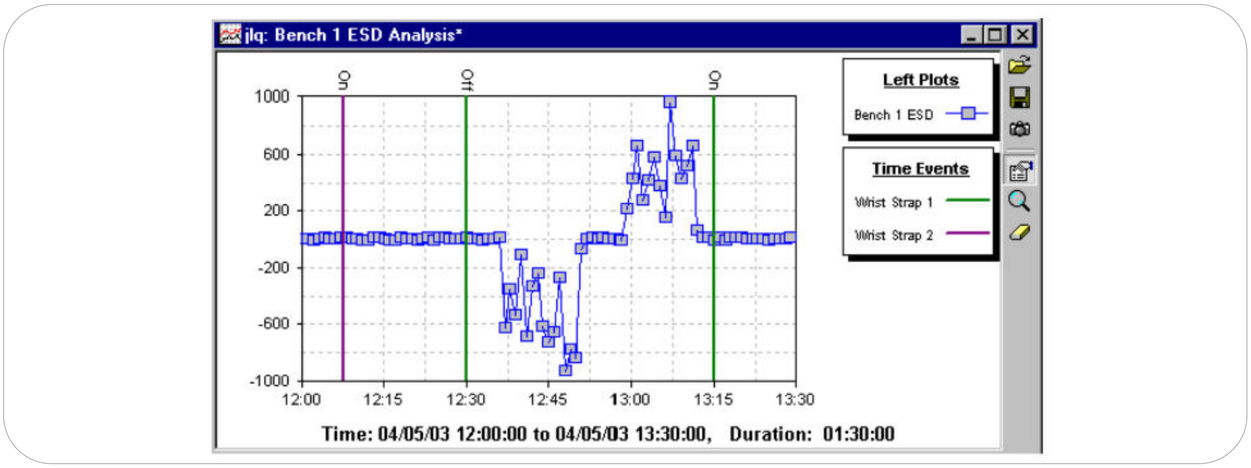
By strategically selecting these sampling locations, a comprehensive and effective monitoring plan can be established, helping to maintain the stringent cleanliness standards required in semiconductor manufacturing.

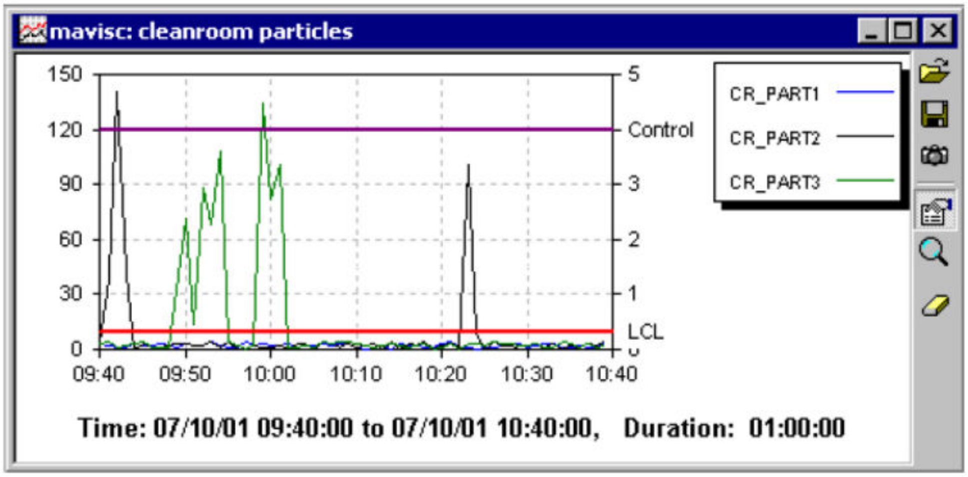
Trending Graphs and Reports

Crucial to the sample locations the trending settings are important to ensure that cleanroom operators and managers have easy to follow trending visuals so any shifts from normal conditions are quickly notified and viewed. Contamination events can impact yields and yield deviations as much as 0.5% can impact on the bottom line as much as tens of millions of dollars.

Therefore, it is important that trending graphs are setup so the manifold data can be visualized easily by operators and proper notifications for Alert and Action alarms are sent to key decision makers.







Example of Trends that support Action and Alerts in various sampling locations

Summary of "Particle Counter Manifold Systems in the Semiconductor Industry"

The technical paper explores the significant role of particle counter manifold systems in maintaining contamination control within semiconductor and LCD manufacturing environments. These environments require stringent cleanliness standards due to the sensitivity of products like microcontrollers, sensors, actuators, digital signal processors, and various display technologies.

Importance of Particle Monitoring

Particle monitoring is integral to contamination control in semiconductor manufacturing. Optical particle counters measure particle levels in cleanroom air, as well as in gases, water, and chemicals used during manufacturing processes. As semiconductor production advances, new demands are placed on optical particle counting technology and monitoring systems to ensure high yield and efficiency.

Advantages of Manifold Systems

Manifold systems offer a cost-effective alternative to real-time monitoring systems, which require remote particle counters at each monitoring location. A manifold system uses a single particle counter connected to multiple sampling points via a mechanical alignment system. This setup reduces equipment costs and simplifies maintenance, particularly in large-scale cleanrooms where individual monitoring points would be impractical.

Design and Functionality

A manifold system can have multiple ports (ranging from 5 to 32) connected to a single particle counter. These systems operate sequentially, sampling from various points to provide comprehensive monitoring. The design of manifold systems focuses on optimal flow efficiency, avoiding right angles to ensure smooth particle transport. Additionally, they must prevent particle generation from internal mechanisms or cross-contamination.

Practical Applications

In semiconductor fabs, centralized cleanrooms and minienvironments around process tools are used to isolate contaminants effectively. Fabs generally adhere to the ISO 14644-1 standard for cleanliness certification, which involves monitoring particle levels using particle counters. The data collected helps in identifying contamination sources and correlating them with product yield, thereby enabling timely corrective actions.

Installation and Setup

Installation of manifold systems, like the UM-II Manifold by Lighthouse Worldwide Systems, involves connecting sample tubing to the manifold and configuring the system to sequentially sample from selected points. Proper installation parameters, such as tubing length and flow rates, are critical to ensure accurate monitoring. The manifold controller interfaces with the particle counter and can be integrated with facility management systems for remote monitoring and control.

Monitoring Locations

Key sampling locations in a cleanroom include critical process areas, minienvironments, workstations, gowning and entry areas, air showers, return air ducts, HEPA filters, and high-traffic areas. By strategically selecting these locations, a comprehensive and effective monitoring plan can be established to maintain the cleanliness standards required in semiconductor manufacturing.

Visual Trends and Notifications

Trend graphs and alarm notifications play a crucial role in the effective utilization of manifold systems. These visual tools provide operators with real-time insights into particle levels and contamination trends. By displaying data trends graphically, operators can quickly identify deviations from normal conditions, allowing for immediate intervention to prevent potential yield losses. Trend graphs also support better decision-making by highlighting contamination events and their impact on yield performance. Alerts and notifications from these graphs enable prompt action, ensuring the cleanroom environment remains within specified cleanliness standards.

Conclusion

Particle counter manifold systems are essential for effective contamination control in semiconductor cleanrooms. They provide a practical and economical solution for monitoring multiple points, ensuring that contamination is detected and managed efficiently, thereby supporting high product yields and manufacturing efficiency.

Expand Your Knowledge

Lighthouse Worldwide Solutions offers comprehensive and industry standard-setting options for both possibilities, designed to meet your needs, abide by regulations, and keep your cleanroom clean.

For more information on monitoring for contamination in cleanroom applications visit our knowledge center for the most comprehensive library of cleanroom monitoring applications, webinars, tech papers and more:

www.golighthouse.com/en/knowledge-center/

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