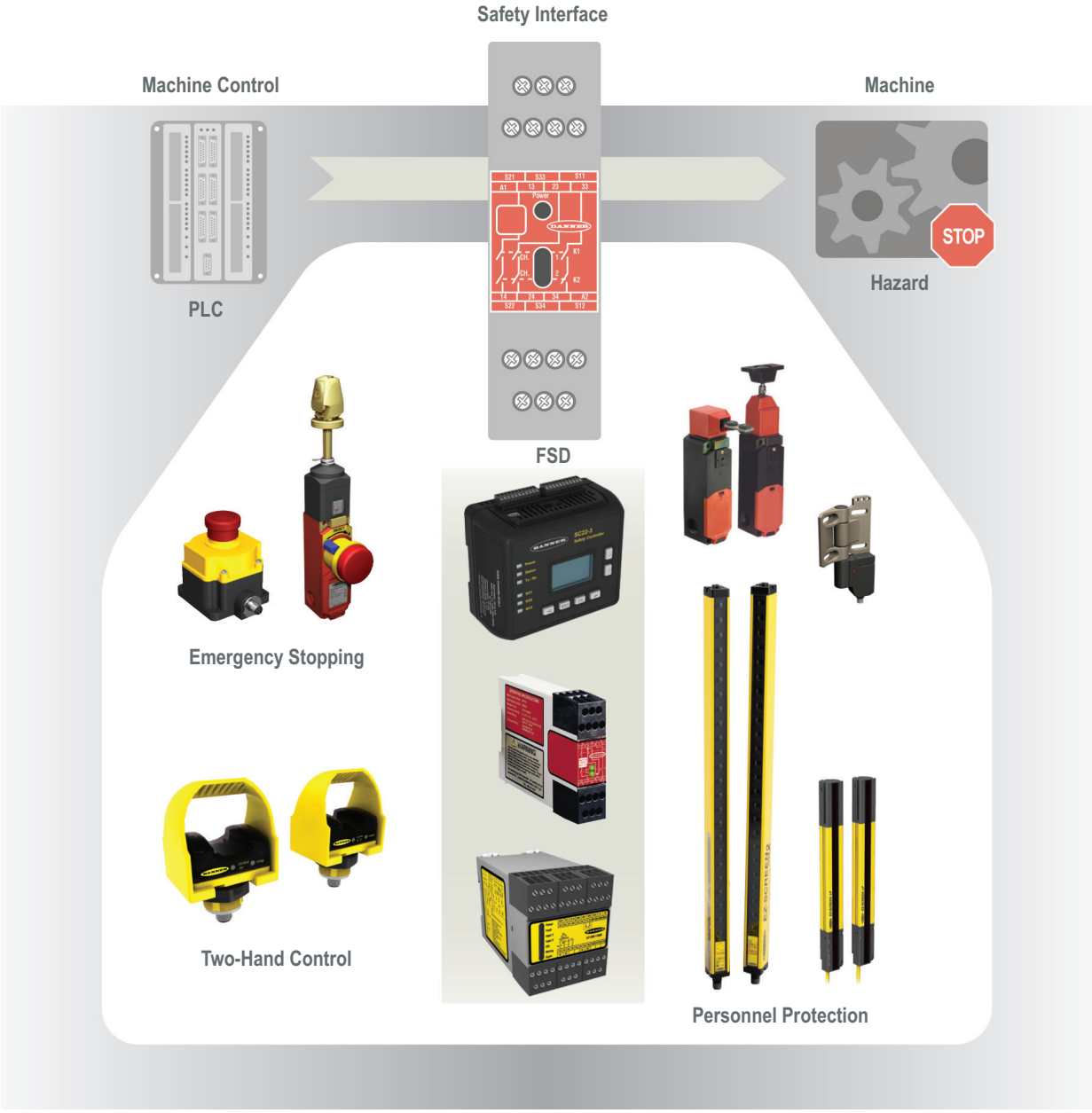
Safeguarding Basics



Basics of Safeguarding
Machine and personnel safeguarding refers to the combination of requirements, methods and solutions used to protect people who come in contact with dangerous machines in the industrial environment.

Requirements
National and regional governmental bodies have regulations, mandates, standards and recommendations for implementing a safety method or a solution.

Key regulations regarding general machine guarding include the following:
- Machinery Directive - EU
- OSHA General Duty Clause – USA

(see page 512 for an abridged version list of industry safety standards)

Device Requirements
Safety devices must be able to consistently and reliably bring a machine hazard to an orderly stop.

To be considered a safety device, the following methods must be used to ensure reliable operation: fault exclusion, redundancy and self-checking.

Safety Circuit Requirements
A safety stop circuit typically comprises of 2 normally-open contact from mechanically-linked relays. The circuit is monitored to detect certain failures that could lead to the loss of the safety function.

Methods: Risk Assessment

The Risk Assessment Process in machine safeguarding is a process used to identify hazards through each phase of the machine's life cycle and to minimize dangers to personnel and equipment.

The basic steps in a Risk Assessment Process:

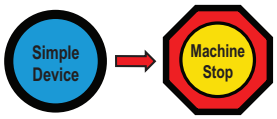
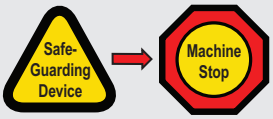
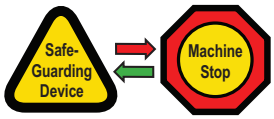
1. Identify hazards and where they occur.
2. Assess risk by severity of harm and probability of occurrence.
3. Reduce the risk through the use of protective measures.
4. Validate and document results.

Risk Assessment Standards

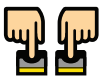
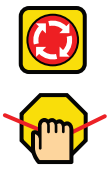
- OSHA 3071, Job Hazard Analysis
- MIL-STD-8820, US DOD System Safety Program
- ANSI B11.0 General (Safety) Requirements and Risk Assessment
- ISO 12100, General Principles for Design, Risk Assessment and Risk Reduction
- SEMI S10, Risk Assessment, Semiconductor Manufacturing Equipment

Methods: Safety Circuits

Depending on the level of risk associated with the machine or operations, an appropriate level of control circuitry performance must be incorporated into safety device design.

	Basic	Single	Single with Monitoring	Dual with Monitoring
Generic	Stop Command	Protective Command	Protective Command Monitoring Signal	Redundant (Safety) Stop Commands Monitoring Signal
				
	• Non safety-rated components • Integrated in accordance with relevant standards • Reliability depends on robust components • Redundancy not required	• Safety-rated components • Integrated in accordance with safety principles and design • Redundancy not required	• Safety-rated components • Conducts periodic test of system • Normal operation allowed if no faults are found • If unsafe fault is found, system will default to safe state or indicate that unsafe system exists	• Safety-rated components • Greatest degree of fault tolerance • Redundancy and self-checking • Single failure cannot cause loss of safety function • Faults detected immediately or at next demand on system
Fault	Possible loss of safety function	Greater reliability, but possible loss of safety function	Fault detected at each test	Safety function is ensured with a single fault. An accumulation of faults is not possible or detected.
Risk	**Very Low** Minor bump or bruise with no lost time	**Low** Minor first aid, infrequent exposure or high likelihood of avoiding the hazard	**Mid Range** Injuries that are slight or normally reversible, requiring normal healing or only first aid	**High or Very High** Normally reserved for hand-fed applications where injuries could be severe to irreversible
ANSI / B11	—	—	—	Control Reliable ANSI B11.19 (Clause 6.1 and Annex C) Category 3 or 4 and/or PL d or PL e per ISO 13849-1 satisfy Control Reliability requirements
ANSI / RIA	Simple	Single Channel	Single Channel with Monitoring	Control Reliable ANSI/RIA R15.06 (1999 Clause 4.5) Control reliability for robots typically exceeds a Cat 3 but is not necessarily intended to be a Cat 4
ISO / EN	Category B ISO 13849-1/EN 954-1	Category 1 ISO 13849-1/EN 954-1	Category 2 ISO 13849-1/EN 954-1	Category 3 & 4 ISO 13849-1/EN 954-1

Solutions: Comparing Guards and Devices*

Type	Safety Function	Advantages	Limitations	Requirements	Standards
Guards: protective physical barrier used to prevent access.					
Fixed Guard 	Provides a fixed barrier to the hazard	• Low maintenance • Long life • Low cost for small areas • Protects all individuals • Can contain ejected materials	• Poor ergonomics • Limited visibility • Limited access • Costly for large areas • Maintenance may require removal of guard	• Protect from identified hazard • Prevent user from reaching over, under, around or through the barrier • Provide safe openings	• ANSI B11.19 • ISO 14120 • ISO 13857
Interlocked Guard 	Interrupts power to machine when guard is opened	• Low initial investment • Can be placed close to hazard • Protects all individuals • Can contain ejected materials	• Costly for large areas • Increased maintenance	• Must be difficult to defeat • Guard may open only after machine has stopped–or must be installed at a safe distance	• ANSI B11.19 • NFPA 79 • ISO 14119 • ISO 14120 • IEC 60204-1 • ISO 13857 • ISO 13855
Safeguarding Devices: components, attachments or mechanisms designed to perform a specific safeguarding function.					
Safety Light Screen 	Arrests power to machine when sensing field is interrupted	• Excellent ergonomics • Allows frequent access • Protects all individuals • Cost effective for large areas • Allows for good visibility	• Limited to machines that can be stopped quickly • No protection from ejected parts • May require the use of additional guards • May create a pass-through hazard	• Initiate immediate stop when sensing field is interrupted • Appropriate resolution required to detect objects the size of a torso, ankle, hand or finger	• ANSI B11.19 • IEC 61496 • ISO 13855
Multiple-Beam System: • Grids • Points 	Arrests power to machine when sensing field is interrupted	• Low initial investment • Allows frequent access • Allows for good visibility • Protects all individuals	• Limited to machines that can be stopped quickly • No protection from ejected parts • Large safety distance • May create a pass-through hazard	• Initiate immediate stop when sensing field is interrupted • Appropriate resolution required to detect objects the size of a torso	• ANSI B11.19 • IEC 61496 • ISO 13855
Two-Hand Control 	Operator must use both hands to actuate machine motion hereby preventing operator access to hazardous area	• Operator's hands are away from hazardous area • Low initial investment • Low maintenance	• Potential ergonomic impact • Provides protection only for operator • No protection from ejected parts	• Concurrent actuation within 1/2 second • Release and reactivation required before machine motion may be reinitiated	• ANSI B11.19 • NFPA 79 • ISO 13851 • IEC 60204-1 • ISO 13855
Safety Mat Monitor 	Interrupts power to machine when a minimum pressure is applied	• Excellent ergonomics • Protects all individuals • Allows for good visibility	• Costly for large areas • Maintenance intensive • Large safety distance	Minimum object sensitivity of 66 lbs on and 3-1/8" surface to detect a foot	• ANSI B11.19 • ISO 13855 • ISO 13856
Complementary Safety Devices: used to supplement a primary safeguard.					
E-Stop • Button • Rope Pull 	Operator activates button in emergency situation to shut off power to machine	• Immediate response • Safe shutdown of machine process	• Not considered a safeguard • Requires conscious act of operator • Limits injury or machine damage but typically does not prevent it	• Overrides all other functions and operations • Reset of E-stop doesn't initiate machine motion • Button must be red with yellow background • Should be located at each operation station • Final removal of power done by electromechanical components	• ANSI B11.19 • NFPA 79 • ISO 12100 • IEC 60204-1 • ISO 13850

*This represents a partial list of available safeguards & devices.

Solutions: Choosing and Locating a Safeguard

When choosing a safeguard, ask yourself the following questions:
1) is it safe, 2) is it legal and 3) does it make sense for the application.

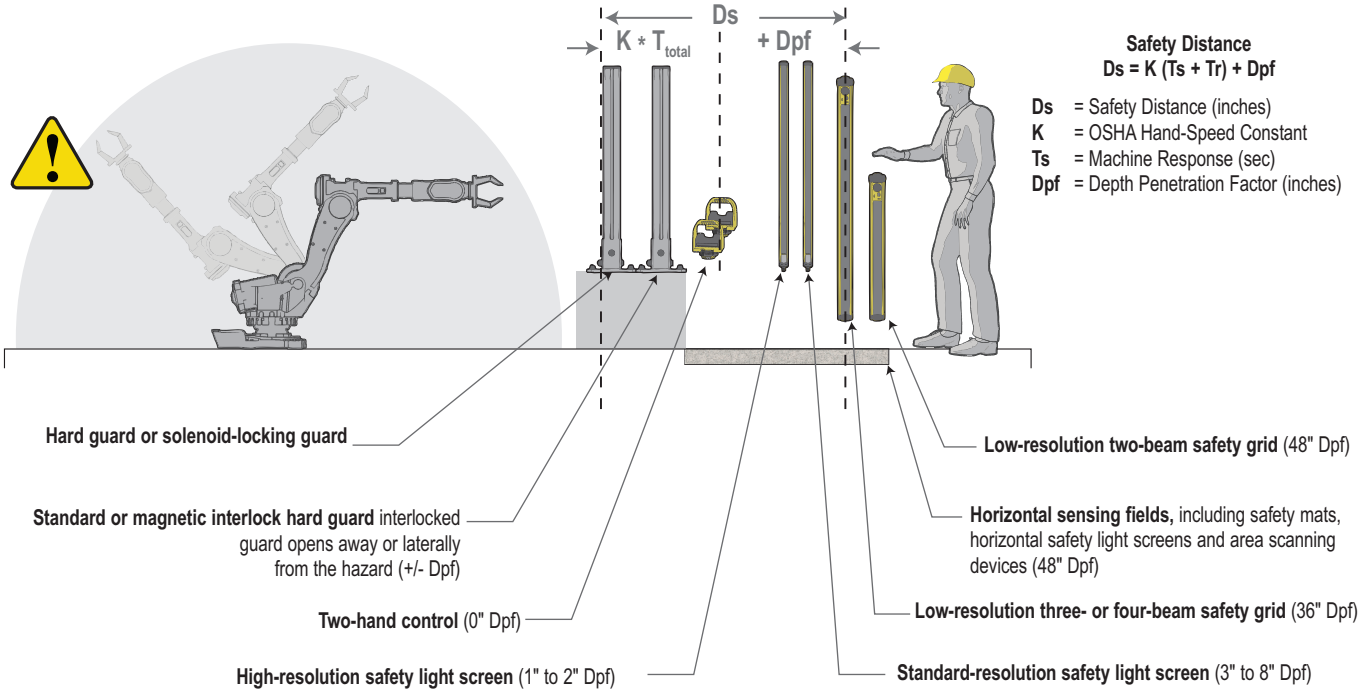
Choosing a Safety Product

- □ Who will use it?
- □ How will they use it?
- □ What hazards are associated with which task?
- □ What are the types of hazards?
- □ Where will the safeguard be located?

E = Excellent
A = Acceptable
P = Poor
X = Not Acceptable

Guarding Solutions	Maintenance $	Frequent Access	Infrequent Access	Locate Close to Hazard	Long Machine Stop Time	Ergonomic	Visibility	Multiple Operators	Guards Against Ejected Material	Comments
Fixed Hard Guard	P	P	E	E	E	P	P	E	E	• Limited access • Limited visibility to the machine • Costly for large areas • Costly to maintain and fix
Locking Guard	P	P	E	E	E	P	P	E	E	
Interlock Guard	P	P	A	E	A	P	P	E	E	
Two-Hand Control	A	A	A	A	A	A	A	P	P	• Only protects operator(s)
High-Resolution SLS	E	E	P	E	P	E	E	E	X	• Locate closer to hazard
Low-Resolution SLS	E	E	P	E	P	E	E	E	X	• Costs less than high resolution SLS
3- or 4-Beam Perimeter	E	A	A	P	A	E	E	E	X	• Takes less space than 2-beam
2-Beam Perimeter	E	A	A	P	A	E	E	E	X	• Costs less than 3- or 4-beam
Safety Mats	P	A	A	P	A	E	E	E	X	• Maintenance-intensive

Locating a Safety Product



NOTE: Illustration examples are based upon the described safeguards being used as the primary safeguarding device, all examples having identical stopping time, and following generally accepted industrial engineering practices that are found within ANSI B11.19 safety standard.

Requirements: Standards

Safety and Safeguarding standards are minimum requirements for product and machine design, manufacture, use and evaluation that guide the methods used to improve safety. Note: The following is not all inclusive and is provided for information only. Superseded designations are contained in parentheses.

General Requirements (A & B standards)

U.S.
OSHA 29CFR1910.212
General Requirements for All Machines
OSHA 3071
Job Hazard Analysis
ANSI B11.0 (ANSI B11.TR3)
General Requirements and Risk Assessment
OSHA 29 CFR 1910.147
The Control of Hazardous Energy (lockout/ tagout)
ANSI Z244.1
Lockout/Tagout of Energy Sources
ANSI/NFPA 79
Electrical Standard for Industrial Machinery

International/European
ISO 12100 (ISO 12100-1/-2 and ISO 14121)
General Principles for Design - Risk Assessment and Risk Reduction
ISO 14118 (EN 1037)
Prevention of Unexpected Start Up
IEC 60204-1
Electrical Equipment of Machines: General Requirements

Safety and Safeguarding Design

U.S.
ANSI B11.19
Performance Criteria for Safeguarding
ANSI B11.20
Integrated Manufacturing Systems
ANSI B11.24
Transfer Machines
ANSI B11.TR1
Ergonomic Guidelines
ANSI B11.TR5
Sound Level Measurement Guidelines
ANSI B11.TR6
Safety Control Systems
ANSI Z535 series
Safety Signs, Tags/Labels, Symbols, Color Codes and Manuals/Instructions

International/European
ISO 11161
Integrated Manufacturing Systems
ISO 14119 (EN 1088)
Interlocking Devices Associated with Guards
ISO 14120 (EN 953)
Guards
ISO 13849-1 (EN 954-1)
Safety Related Parts of Control Systems
ISO 13850 (EN 418)
Emergency Stop Devices
ISO 13851 (EN 574)
Two-Hand Control Devices
ISO 13854 (EN 349)
Minimum gaps to avoid crushing of parts of the human body
ISO 13855 (EN 999)
The Positioning of Protective Equipment
ISO 13857 (ISO 13852/EN 294, ISO 13853/EN 811)
Safety Distances [openings] - Upper and Lower Limbs
IEC 61508
Functional Safety of electrical/electronic/programmable electronic safety-related systems
ISO 62061
Functional Safety of Safety-Related Electrical, Electronic and Programmable Control Systems

Machine Specific Applications, Grouped by Type (C Standards)
Mechanical Power Transmission Apparatus
OSHA 29CFR1910.219
Note: ANSI/ASME B15.1 Mechanical Power Transmission Apparatus has been incorporated into ANSI B11.0 & ANSI B11.19.

Machine Tools- Mechanical Power Presses
(Note: Refer to the ANSI B11.xx series for additional Machine Tool standards)
OSHA 29CFR1910.217
ANSI B11.1
EN 692

Conveyors
ANSI/ASME B20.1
ISO 9851

Industrial Robots
ANSI/RIA R15.06
ISO 10218 (EN 775)

Injection Molding / Extruding (Rubber & Plastics)
ANSI B151.xx series
EN 201
EN 1114-1
EN289
EN422
EN1612

Mills and Calenders
OSHA 29CFR1910.261
OSHA 29CFR1910.216
ANSI B28.1
EN 1417

Packaging
ANSI/PMMI B155.1
EN 415 series

Semiconductor
SEMI Sxx series
SEMI S2
SEMI S10

Lasers
ANSI Z136.1
ANSI B11.21

Turning Machines / Machining Centers
ANSI B11.22
ANSI B11.23

These and other standards are available from:
OSHA Documents: *http://www.osha.gov*
American National Standards Institute (ANSI): *http://www.ansi.org*
NSSN National Resource for Global Standards: *http://www.nssn.org/*

Safety Standards Acronyms

ANSI: American National Standards Institute
CE: Mark of European Conformity
CEN: European Committee for Standardization
CENELEC: European Committee for Electrotechnical Standardization
CSA: Canadian Standards Association
EN: European Norm
IEC: International Electrotechnical Commission
ISO: International Organization for Standardization
OSHA: Occupation Safety and Health Administration
SEMI: Semiconductor Equipment and Materials International
UL: Underwriters Laboratory