UNIVERSAL ROBOTS

Safety Guide

February 1, 2013

1 Introduction

This guide gives a short introduction to directives and standards followed by an overview of how to make the necessary documentation for a simple robot installation.

2 Understanding Directives and Standards

The two following subsections describes directives and standards independently. A summary is shown in the table below.

Directive	Law made by the European Commission
CE mark	A mark that indicates compliance with some directives
Harmonized standard	If you comply with the standard then you comply with a directive
A standard	Basic safety standard
B standard	Generic safety standard
C standard	Machine specific safety standard
Norm	Just another word for standard

2.1 Directives

All laws made by EU are called directives. Directives dictates how a member state shall make its local laws within a specific field. The local laws must not be harder nor softer than the directives. Most directives are just translated into the language of the state and implemented as law directly. Regarding safety there are two directives which covers most products; The machinery directive (called 2006/42/EC by EU and sometimes just MD) and the low voltage directive (called 2006/95/EC by EU and sometimes just LVD). Since both directives regards safety only one of them is applied to a specific product. A robot is covered by the MD because the main hazards are mechanical movements and not electrical shock.

According to article 6 of the MD member states shall not prohibit, restrict or impede the placing on the market and/or putting into service in their territory of machinery which complies with this directive.

Some directives including the MD force the producer to put a CE on the completed machinery. The CE mark indicates that the product comply with the directive covering the main hazards of the product. Partly completed machinery, such as a Universal Robot, are not allowed to have a CE mark whereas a robot installation with a Universal Robot must have a CE mark.

The MD can be found on the official homepage of the European Commission http://ec.europa.eu or by searching for "2006/42/EC" on google.com.

2.2 Standards

All standards are voluntary. There are no laws that forces products to comply with any standards. However, standards help both integrators and end users by specifying safety requirements, performance characteristics, interfaces etc.

Some standards are special because they are harmonized under a specific directive. If a machine or installation comply with a standard harmonized to the MD then the machine or installation also comply with the MD. A harmonized

standard is often very specific and therefor easier to fulfill than a directive. To see whether a standard is harmonized and to which directive you must check if there is one or more Annex Zs (ZA, ZB etc.). The annexes can be placed in both the beginning and the end of the standard.

Standards for machine safety are divided into A, B or C types. A type-A standard gives basic concepts, principles of design and general aspects that can be applied to machinery (i.g. EN ISO 14121-1[1]). A type-B standard is dealing with one safety aspect or one type of safeguard that can be used across a wide range of machinery (i.g. EN ISO 13850[2]). A type-C standard is dealing with detailed safety requirements for a paticular machine or group of machines (i.g. EN ISO 10218-1[3]).

When a type-C standard deviates from one or more provisions dealt with by a type-B or type-A standard the type-C standard takes precedence. To check the type of a standard you must look under the introduction of the standard (in special cases under foreword).

Whenever you refer to a standard it is important to specify the full name including all the letters (i.g. EN ISO ...) and sometimes also the date of approval (i.g. :2008).

Note that "norm" is just a synonym for standard, which typically is used in France.

3 Necessary Documentation

This section describes how a robot integrator can make the necessary documentation for a simple robot installation. This document assumes that the integrator is based within the EU, that the installation is put into service within the EU and that all documentation is written in an official community language.

A robot installation must comply with the machinery directive (MD). This includes the following points.

1. Make sure that the product comply with all essential requirements.
2. Make a risk assessment.
3. Clarify instructions for the operator.
4. Make a declaration of conformity.
5. Collect all information in a technical file.
6. Put a CE mark on the robot installation.

An installation is typically covered by other directives like a Universal Robot is covered by the EMC (ElectroMagnetic Compatibility - 2004/108/EC) and RoHS directive (Restriction of the use of certain Hazardous Substances in electrical and electronic equipment - 2002/95/EC).

The EMC directive insures that different electrical equipment do not interfere with each other through cables or by electromagnetic waves. It also insures that the equipment is not sensitive to electrical disturbing elements like lightning and ESD (ElectroStatic Discharge). An integrator is combining components and partly completed machinery and all these must already comply with the EMC

[1] EN ISO 14121-1 "Safety of machinery - Risk assessment - Part 1: Principles"
[2] EN ISO 13850 "Safety of machinery - Emergency stop - Principles for design"
[3] EN ISO 10218-1 "Robots for industrial environments - Safety requirements - Part 1: Robot"

directive. The only thing that the integrator needs to ensure is that the installation instructions for every part is followed.

The RoHS directive protects the environment from hazardous substances like mercury, lead and bromide flame retardants. But again, all components must already comply, and the compliance of a robot installation is therefore easily achieved.

Remember that you can always contact national authorities if you have any questions.

Note that the responsibility for complying with all relevant directives belongs to the integrator alone. Universal Robots only take responsibility for the compliance of the robot. This is just a guide.

3.1 Compliance with Essential Requirements

The first thing to check is if the final machinery or robot installation is especially dangerous machinery falling into one of the categories listed in annex IV of the MD. Less than 1% of all robot installations fall into one of these categories but if they do, special procedures described in Article 12(3) and (4) of the MD must be applied. If the robot installation is not covered by annex IV all tests and documentation can be carried out by the integrator without use of third party consultants.

It is recommended to read the entire MD or corresponding local law to ensure compliance. However, the essential health and safety requirements is listed in annex I of the MD. This annex can be used to lookup specific issues such as "Emergency stop" (1.2.4.3) or "Control of movements" (4.1.2.6). Most people find that these essential requirements is no more than common sense. It is important to remember that the goal is to produce safe robot installations and not to make them complicated.

When a robot installation is more complex it is recommended to follow the two harmonized standards EN ISO 12100-1 (Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology) and EN ISO 12100-2 (Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles).

Note point 3 of general principles in annex I: The essential health and safety requirements laid down in this Annex are mandatory; However, taking into account the state of the art, it may not be possible to meet the objectives set by them. In that event, the machinery must, as far as possible, be designed and constructed with the purpose of approaching these objectives.

3.2 Risk Assessment

One of the most important things that an integrator needs to do is to make a risk assessment. Annex I point 1 describes specifically how it should be done as listed below. Note that the significance of a hazard depends upon both damage and probability. It can be acceptable to have a risk of getting a blue nail if it is very unlikely and if the operator does something very stupid.

1. Determine the limits of the machinery, which include the intended use and any reasonably foreseeable misuse thereof.

2. Identify the hazards that can be generated by the machinery and the associated hazardous situations.

3. Estimate the risks, taking into account the severity of the possible injury or damage to health and the probability of its occurrence.

4. Evaluate the risks, with in view of determining whether risk reduction is required, in accordance with the objective of the MD.

5. Eliminate the hazards or reduce the risks associated with these hazards by application of protective measures, by applying the appropriate principles, in the priority given below:

   a) Eliminate or reduce risks as far as possible (inherently safe machinery design and construction).

   b) Take the necessary protective measures in relation to risks that cannot be eliminated.

   c) Inform users of the residual risks due to any shortcomings of the protective measures adopted, indicate whether any particular training is required and specify any need to provide personal protective equipment.

Every time a change of design is made to reduce a risk, the procedure must be restarted because new hazards may have occurred. It is important to document the whole process including a list of all the identified hazards. The used risk assessment procedure must also be documented. When a robot installation is more complex it is recommended to follow EN ISO 14121-1[4], which is harmonized under the MD. ISO/TR 14121-2[5] can be very useful as well.

Universal Robots has identified the potential significant hazards listed below as hazards which must be considered by the integrator. Note that other significant hazards might be present in a specific robot installation.

1. Entrapment of fingers between robot foot and base (joint 0).

2. Entrapment of fingers between the small tube and wrist (joint 4).

3. Penetration of skin by sharp edges and sharp points on tool or tool connector.

4. Penetration of skin by sharp edges and sharp points on obstacles that the robot moves close by.

5. Bruising due to stroke from the robot.

6. Sprain or bone fracture due to strokes between a heavy payload and a hard surface.

7. Consequences due to loose bolts that keep robotic arm or tool.

8. Electrical shock or fire due to malfunction of power supplies if the mains connection is not protected by a HFI or HPFI relay.

9. Electrical shock due to malfunction of power supplies if the control box is not connected to earth through mains cable.

However, the Universal Robot is a very safe robot due to the following reasons:

[4]EN ISO 14121-1 "Safety of machinery - Risk assessment - Part 1: Principles"

[5]ISO/TR 14121-2 "Safety of machinery - Risk assessment - Part 2: Practical guidance and examples of methods"

1. Control system is Category 3 performance level **d**
2. High level software generates a protective stop if the robot hits something. This stop force limit is lower than $150N$.
3. Furthermore, low level software limits the torque generated by the joints, permitting only a small deviation from the expected torque.
4. The software prevents program execution when the robot is mounted differently than specified in the setup.
5. The control system of the robot is redundant so that one system error will stop or power off the robot.
6. The weight of the robot is relative low.
7. The robot shape is smooth, to reduces pressure (N/m^2) per force (N).
8. It is possible to move the joint of an unpowered robot (against the brakes) by pulling hard. This feature is, however, only for emergencies as it might reduce the lifetime of the robot.

The fact that the robot is very safe opens the possibility of saving the safety guards or using safety guards with a low performance level. As a help in convincing costumers and local authorities the Universal Robot has been tested by Danish Technological Institute which is Notified Body under the MD in Denmark. The test concludes that the robot complies with point 5.10.5 of the standard EN ISO 10218-1:2006. This standard is harmonized under the MD and it specifically states that a robot can operate as a collaborative robot (i.e. without safety guards between the robot and the operator) if it is in compliance with point 5.10.5. The risk assessment still needs to conclude that the overall robot installation is safe enough of course. A copy of the test report can be requested from Universal Robots.

3.3 Instructions for the Operator

It is important that the integrator gives appropriate instructions for the operator (i.g. manual, descriptions, warning stickers) to insure that the machinery is installed and operated safely and as intended. The formalities below must be applied.

1. If the instructions is translated, the translation must be accompanied by the original instructions.
2. The words "Original instructions" must appear on the language version(s) verified by the integrator.
3. By way of exception, the maintenance instructions intended for use by specialised personnel mandated by the integrator may be supplied in only one language which the specialised personnel understand.
4. The contents of the instructions must cover not only the intended use of the machinery but also take into account any reasonably foreseeable misuse thereof.

5. When the machinery is intended to be used by non-professional operators, the wording and layout of the instructions for use must take into account the level of general education and acumen that can reasonably be expected from such operators.

6. Each instructions manual must contain the declaration of conformity (see next subsection 3.4).

7. Each instruction manual must contain, where applicable, at least the information given in the check list 1.7.4.2. (Contents of the instructions) of annex I of the MD.

3.4 Declaration of Conformity

The declaration of conformity is a small document which specifies the contact information of the producer and declares that the machinery is in conformity with the MD. Annex II of the MD is a check list specifying exactly what to write in this document. The Universal Robot itself has a declaration which only apply to partly completed machinery. The declaration of incorporation of partly completed machinery of the robot is very similar to the declaration of conformity that the integrator must make. The declaration of robot is found in the manual under the chapter called "Warranties and Declarations".

3.5 Technical File

The technical file is merely a collection of all relevant considerations and documents used by the integrator to make the robot installation. The technical file is often confidential to the costumers and is only used by the integrator. The national authorities can request this file if they think the robot installation is dangerous or if a person is badly injured. The integrator often has several days or weeks to assemble the different parts of the technical file when requested, depending on the complexity of the installation. The technical file must be stored for at least 10 years and can be on different medias i.g. paper and computer files.

The technical file is often a collection of all the documents from the used components, drawings of constructed mechanics, schematics, and all the documents made by following this guide. Annex VII of the MD is a check list.

3.6 CE mark

The CE conformity mark must be drawn as two half circles as shown below. The mark must be at least 5mm high, visibly, legibly, indelibly and printed on the same label as the company name and address of the integrator. The robot installation must also be marked with a designation of function, series, type, production year and serial number (if any).