

In this assignment, you will review some basic knowledge of KUKA Robotics, including safety, work envelope, work cell, primary components, screen displays, axis-specific motion, coordinate systems, tools, and operation. First, we will begin with safety and risks. As with any piece of equipment there are risks and dangers if not used properly especially with such large scale industrial robotics such as our KUKA robot arm.

It is essential to remember and follow these key safety points to avoid injury to yourself and others. In the photos below are examples of the different zones, collision risks, risk of electrocution, and warnings to observe which can seriously harm an individual. Once you have complete understanding of the risks and dangers of operating a KUKA robot arm you can continue on to learn the other items mentioned to the left.

## Key Safety Points

1. One person in the cage at a time while operating the robot arm. If multiple operators are needed to avoid injuries:
  - All persons must have an unimpeded view of the robot
  - Eye-contact between all persons must be possible at all times
  - Openly communicate with those around with confirmation that the communication has been received
2. While operating the robot arm stay inside the safety zone to avoid the risks associated shown in the diagram to the right \*this area will be marked on the floor with colored tape\*
3. Always test any movements planned and when testing a manual movement or a programmed script always test in T1 (manual reduced velocity mode).
4. Never touch or approach the robot arm while it is moving or stand underneath it ever.
5. Handle the areas of high voltage risk (shown to the right) with caution and if necessary the proper PPE.
6. Always properly secure a tool and turn off if necessary to avoid any injuries. When finished always remove and store tool properly.
7. Always set a base and touch point for each project with as much accuracy as possible.
8. Be aware of your surroundings while operating and do not leave it operating unattended.
9. If you are unsure of anything always contact the staff.
10. If something goes wrong or you suspect something to go wrong immediately stop the machine or hit the emergency stop if necessary.
11. Always make sure the space is clean after use and that the doors are locked when finished.
12. When operating in T2 (manual high velocity mode) there should never be anyone in the cage or out of the safety zone.
13. Avoid lock up and over extension of the axes and robot arm.

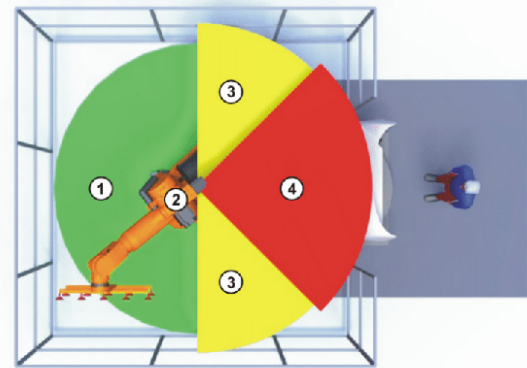


Fig. 2-1: Example of axis range A1

- |   |             |   |                   |
|---|-------------|---|-------------------|
| 1 | Workspace   | 3 | Stopping distance |
| 2 | Manipulator | 4 | Safety zone       |



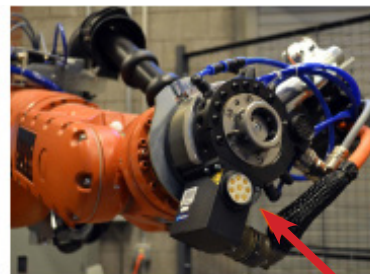
TOOLING RISK



PINCH RISK



STRIKE RISK



HIGH VOLTAGE RISK

# Basics to Robotics- KUKA Parts and Terms 3b

In this assignment, you will review some basic knowledge of KUKA Robotics, including safety, work envelope, work cell, primary components, screen displays, axis-specific motion, coordinate systems, and tools. Now, we will continue with the important terms to remember and the main components of a KUKA robot arm system.

An industrial robot is a re-programmable, multi-functional manipulator designed to move material, machine tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. A robot arm is the combination of the axes, motor, joints, and the links connecting them.

## Important Terms

**Axis Range** of each axis, in degrees or millimeters, within which it may move. The axis range must be defined for each axis.

**Stopping Distance**- Stopping Distance = reaction distance + braking distance. The stopping distance is part of the danger zone.

**Operator (User)**- The user of the industrial robot can be the management, employer or delegated person responsible for use of the industrial robot.

**Danger Zone**- The danger zone consists of the workspace and the stopping distances.

**KCP**- KUKA Control Panel, the KCP has all the operator control and display functions required for operating and programming the industrial robot.

**KUKA smartPAD**- The smartPAD has all the operator control and display functions required for operating and programming the industrial robot.

**Manipulator**- The robot arm and the associated electrical installations.

**Safety Zone**- The safety zone is situated outside the danger zone

**Stop Category 0**- The drives are deactivated immediately and the brakes are applied. The manipulator and any external axes (optional) perform path-oriented braking.

**Stop Category 1**- The manipulator and any external axes (optional) perform path-maintaining braking. The drives are deactivated after 1s and the brakes are applied.

**Stop Category 2**- The drives are not deactivated and the brakes are not applied. The manipulator and any external axes (optional) are braked with a normal braking ramp.

**T1**- Test Mode, manual reduced velocity (<= 250 mm/s)

**T2**- Test Mode, manual high velocity (>250 mm/s permissible)

**External Axis**- Motion axis which is not part of the manipulator but which is controlled using the robot controller

## The Three Primary Components Of An Industrial Robot System



Teach Pendant  
"smartPAD"



Control Cabinet



KR60-3 KUKA Robot ARM

In this assignment, you will review some basic knowledge of KUKA Robotics, including safety, work envelope, work cell, primary components, screen displays, axis-specific motion, coordinate systems, and tools. Now, we will continue with the workspace and other various terms of a KUKA robot arm system and space.

The work cell, work envelope, and barriers of our KUKA robot arm is shown in the photo below. The pinch points safety risks covered in the safety portion will occur within the work envelope shown in the diagrams below within the full extension radius of the robot arm and attached end of arm tooling (EOAT).

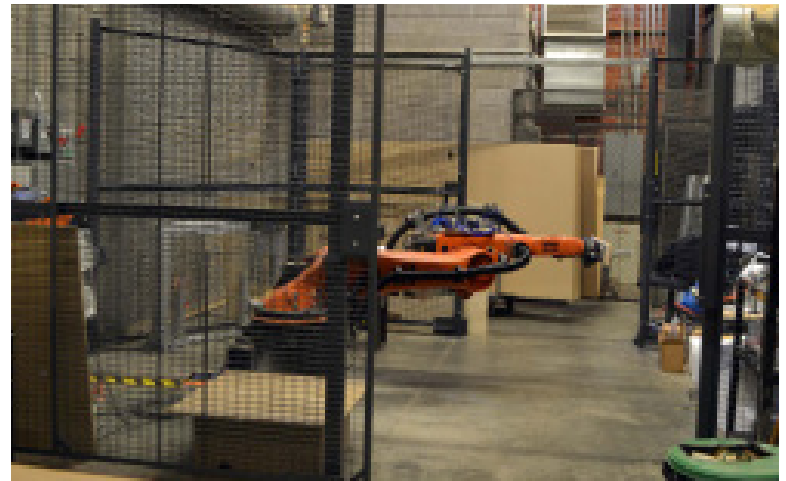
## Terms

### Work Cell: CAP FAB LAB CNC/KUKA Room

The entire room or space that the robot system occupies where people should not be during Auto-mode operations.

### Barriers: Metal Wire Safety Cage

Physical of Safety interlock devices that bound the Work Cell to limit/prevent improper human entrance



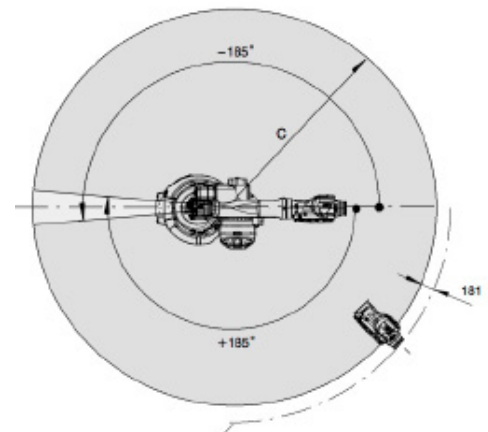
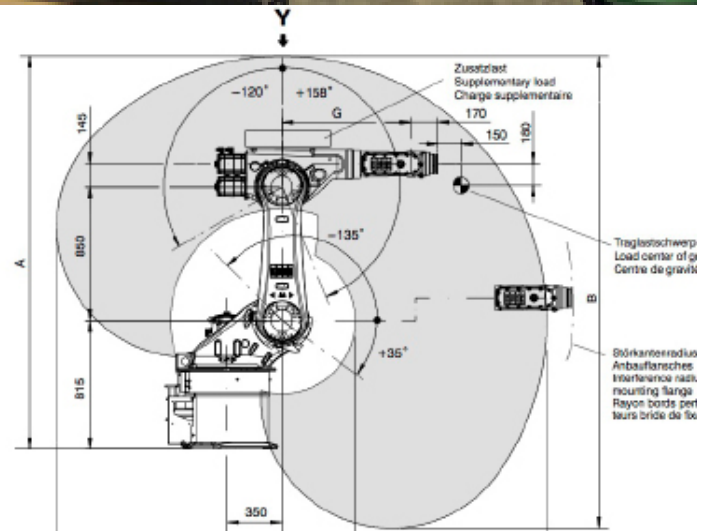
### Work Envelope

Complete space that the Robot Arm + EOAT can reach. IE. the robot's working volume.

### Pinch Points

Please in or on peripheries of the Work Envelope, or Arm, or Tooling, where things can be pinched and/or crushed.

**EOAT = END OF ARM TOOLING**



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Now that you understand some basic terms and components, the workspaces, and the safety and risks you will need to understand how the industrial robot arm creates movement. The large scale industrial robots move mechanically differently at its joints than the small scale UArm desktop. After this you will move forward to the process of operation of the KUKA robot arm.

## Axis-Specific Motion

### AXIS = JOINT = MOTOR

The center of rotation that connects and rotates the links of the robot arm using a servo-motor.

### 1-3: POSITIONING

Typically used for tool

### 4-6: ORIENTATION

Typically used for tool

### Angle of Rotation About and Axis

Angle A = Z Axis

Angle B = Y Axis

Angle C = X Axis

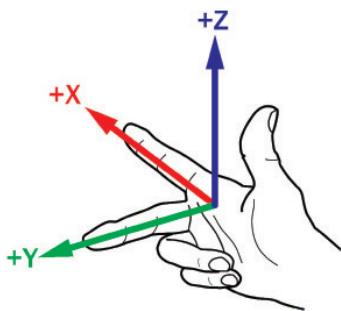
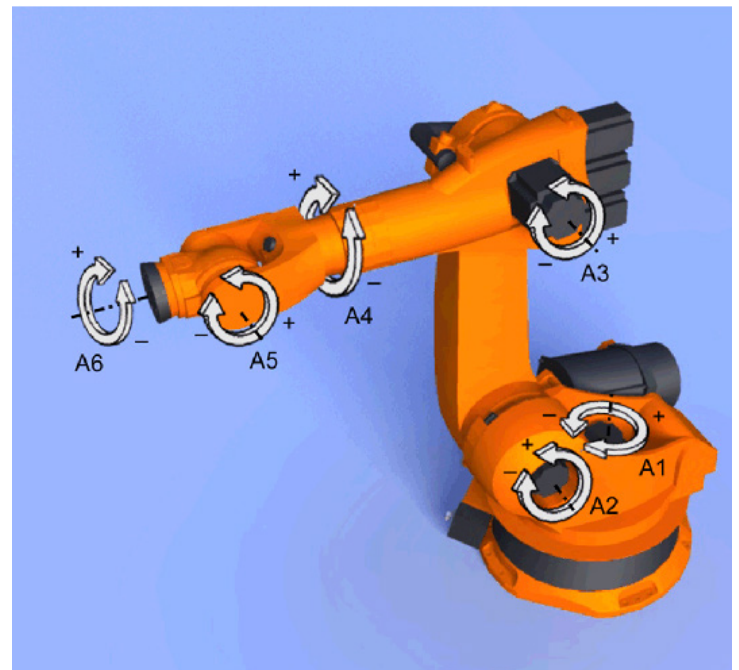
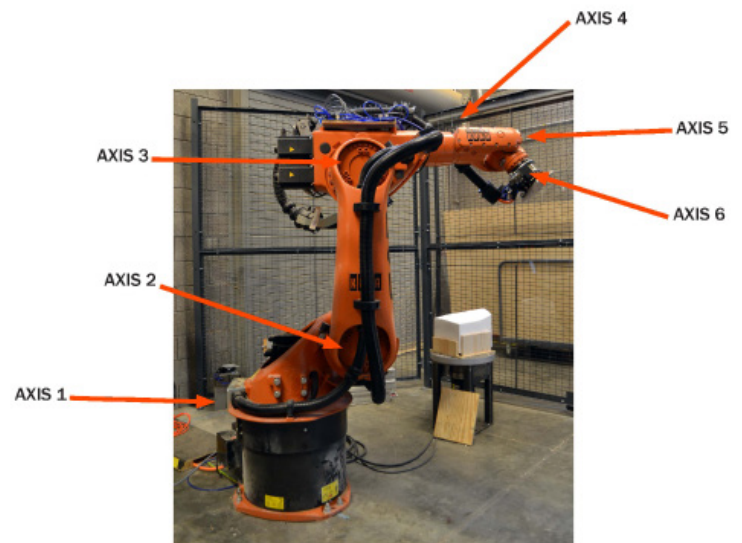
### Right Hand Rule

Used for right-handed coordinate systems

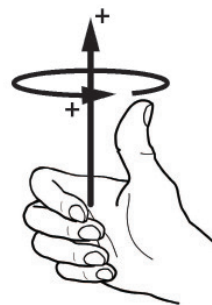
Thumb = Z Axis

Index finger = X Axis

Middle finger = Y Axis



ROBOT RIGHTHAND RULE



RIGHTHAND ROTATION RULE



In this assignment, you will review some basic knowledge of KUKA Robotics, including safety, work envelope, work cell, primary components, screen displays, axis-specific motion, coordinate systems, and tools. Now, we will continue with various types of coordinate systems that the of a KUKA robot arm system requires to understand where, how it needs to move, and understand the space around it.

When creating a new program for an industrial robot it requires different sets of knowledge to be able to complete the program. These sets of knowledge are the guidance system for robot arm to understand what tool it has and what base it uses as a reference frame to know where to go in respect to its own robot base and the world coordinate system around them. These are based on axis directions and targets, or points, that create paths to follow.

## Overview of Coordinate Systems

### WORLD

The WORLD coordinate system is a permanently defined Cartesian coordinate system. It is the root coordinate system for the ROBROOT and BASE coordinate systems. By default, the WORLD coordinate system is located at the robot base.

### ROBROOT

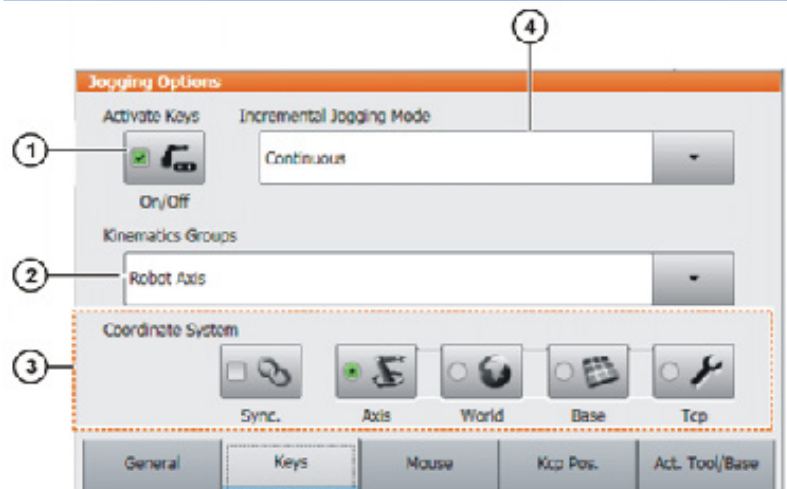
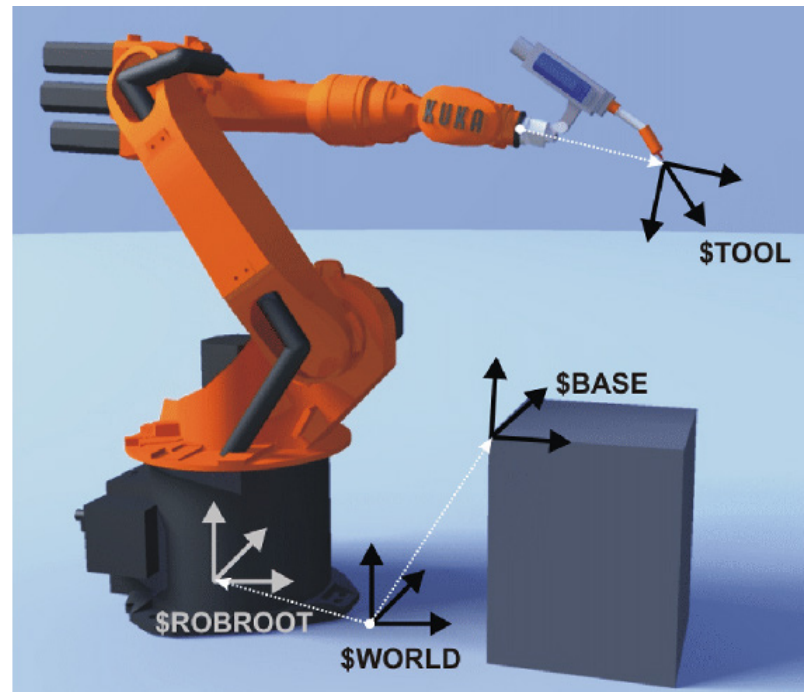
The ROBROOT coordinate system is a Cartesian coordinate system, which is always located at the robot base. It defines the position of the robot relative to the WORLD coordinate system. By default, the ROBROOT coordinate system is identical to the WORLD coordinate system. \$ROBROOT allows the definition of an offset of the robot relative to the WORLD coordinate system.

### BASE

The BASE coordinate system is a Cartesian coordinate system that defines the position of the workpiece. It is relative to the WORLD coordinate system. By default, the BASE coordinate system is identical to the WORLD coordinate system. It is offset to the workpiece by the user.

### TOOL

The TOOL coordinate system is a Cartesian coordinate system which is located at the tool center point. By default, the origin of the TOOL coordinate system is located at the flange center point. (In this case it is called the FLANGE coordinate system.) The TOOL coordinate system is offset to the tool center point by the user.



## Types of Jogging Motion

### Cartesian Jogging

The TCP is jogged in the positive or negative direction along the axes of a coordinate system.

### Axis-Specific Jogging

Each axis can be moved individually in a positive and negative direction.

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When creating a new program for an industrial robot it requires different sets of knowledge to be able to complete the program. These sets of knowledge are the guidance system for robot arm to understand what type of motion is possible or required to generate the necessary movements. These paths are can vary based on the point data it receives and what is possible as to each has limitations and advantages to how it can preform and move.

## Motion Types

### Point to Point: PTP

The robot guides the TCP along the fastest path to the end point. The fastest path is generally not the shortest path and is thus not a straight line. As the motions of the robot axes are rotational, curved paths can be executed faster than straight paths. The exact path of the motion cannot be predicted.

### Linear: LIN

The robot guides the TCP at a defined velocity along a straight path to the end point.

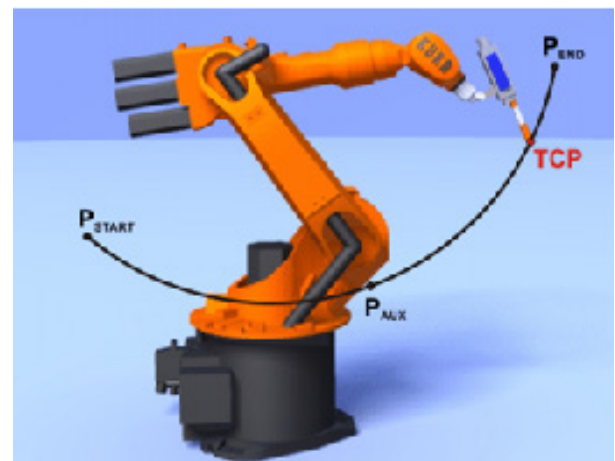
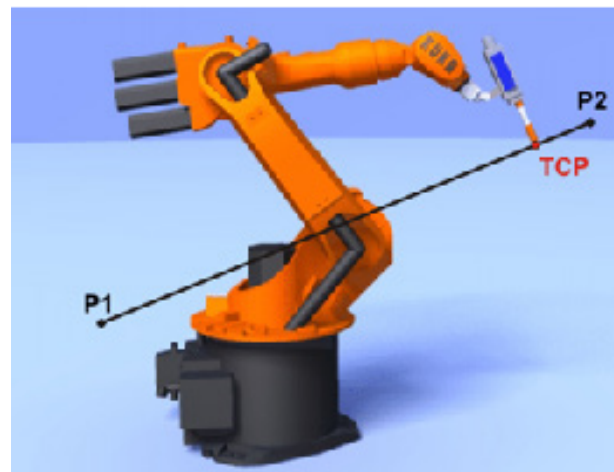
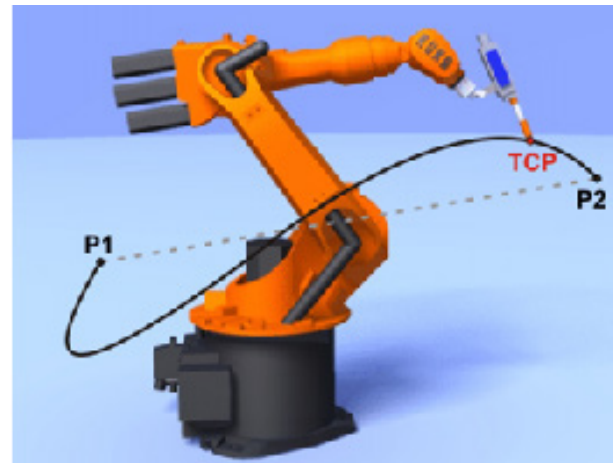
### Circular: CIRC

The robot guides the TCP at a defined velocity along a circular path to the end point. The circular path is defined by a start point, auxiliary point and end point.

### Spline

Spline is a motion type that is particularly suitable for complex, curved paths. Such paths can also be generated using approximated LIN and CIRC motions, but splines have advantages, however. The most versatile spline motion is the spline block. A spline block is used to group together several motions as an overall motion.

The spline block is planned and executed by the robot controller as a single motion block. The motions that may be included in a spline block are called spline segments. They are taught separately. A CP spline block can contain SPL, SLIN and SCIRC segments. A PTP spline block can contain SPTP segments.

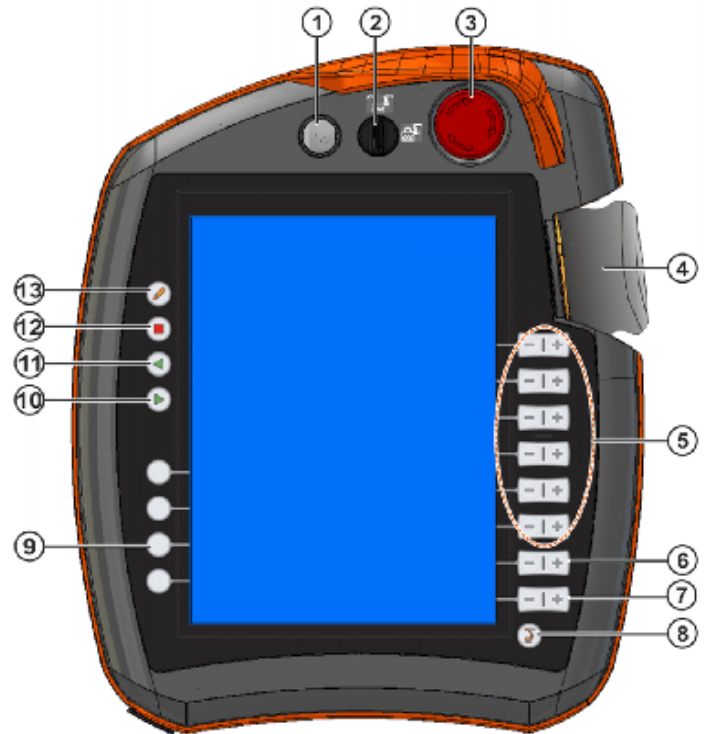


In this assignment, you will review some basic knowledge of KUKA Robotics, including safety, work envelope, work cell, primary components, screen displays, axis-specific motion, coordinate systems, and tools. Now, we will continue with the smartPAD or teach pendant various helpful display screens of a KUKA robot arm system.

The various smartPAD or teach pendant screens are important in the navigation and operation of the industrial KUKA robot arm. This diagram will allow you to familiarize yourself with the teach pendant and navigate the different buttons before operating the industrial KUKA robot arm.

## smartPAD Button Legend: Front

1. Disconnection Button
2. Keyswitch for calling the connection manager
3. Emergency Stop- press to lock and twist to unlock
4. Space Mouse- manual robot movement trigger
5. Jog Keys- manual robot movement of individual axes
6. Key for setting the program override
7. Key for setting the jog override
8. Main Menu Key- shows the menu items on the smartHMI
9. Status Keys- primarily for setting parameters in and dependent of technology packages
10. Start Key- used to start a program
11. Start Backwards Key- used to start a program backwards
12. Stop Key- used to stop a program that is running
13. Keyboard key- displays keyboard



## smartPAD Button Legend: Back

1. Enabling Switch- must be held in the center position in operating modes T1 and T2 in order to be able to jog the manipulator The enabling switch has 3 positions: Not pressed, Center position , Panic position
2. Start Key (Green)- used to start a program
3. Enabling Switch
4. USB Connection
5. Enabling Switch
6. Identification Plate



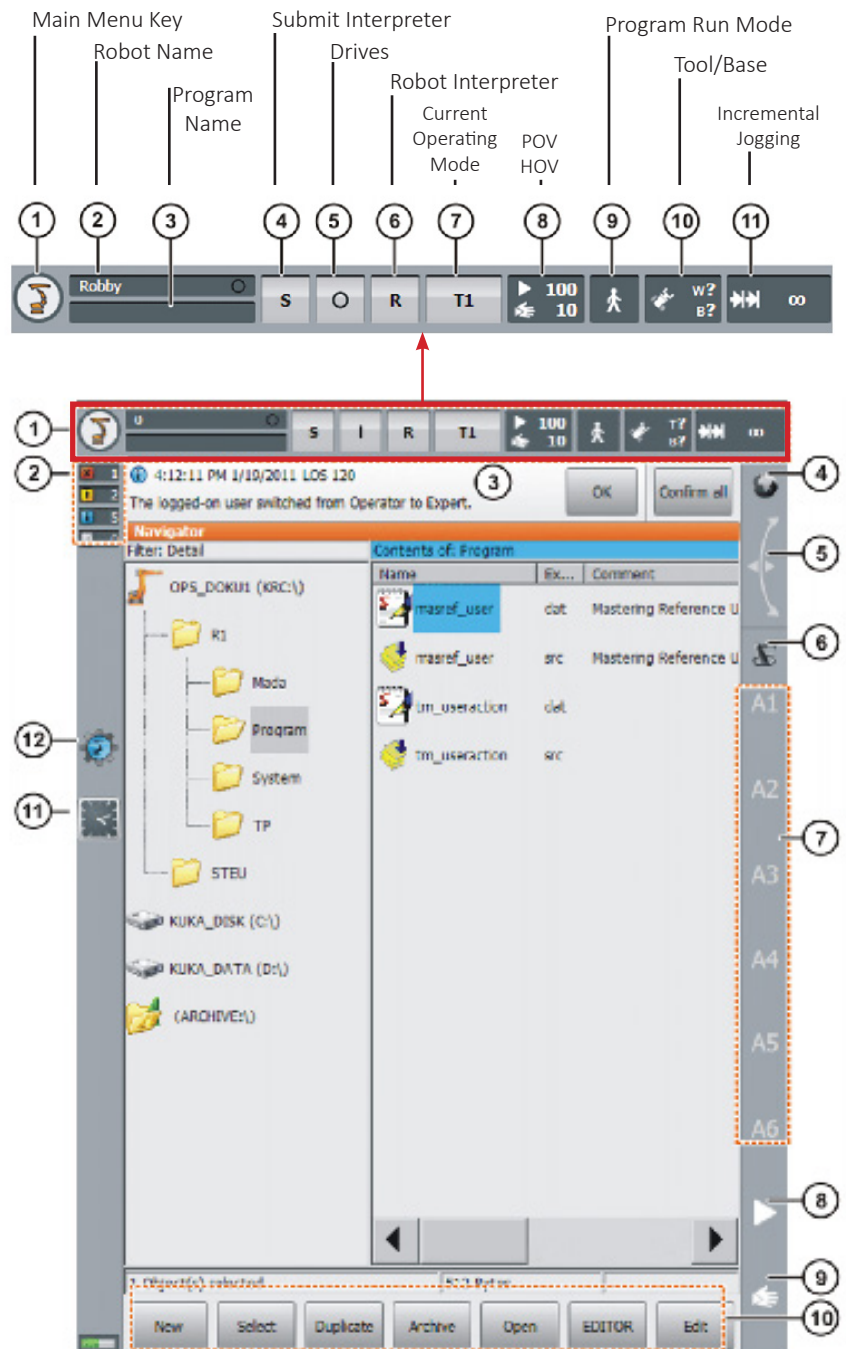


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The various smartPAD or teach pendant screens are important in the navigation and operation of the industrial KUKA robot arm. These screenshots will allow you to familiarize yourself with the teach pendant and navigate the different menus before operating the industrial KUKA robot arm.

## smartPAD User Interface Legend

1. Status Bar
2. Message Counter- indicates how many active messages there are and touching the button will enlarge the display
3. Message window- displays last message and touching will enlarge to display all active messages
4. Space Mouse Status Indicator- shows the current coordinate system for jogging with the Space Mouse and touching displays all coordinate systems allowing you to change systems
5. Space Mouse Alignment Indicator- touching opens a window in which the current alignment of the Space Mouse is indicated and can be changed
6. Jog Keys Status Indicator- shows current coordinate system for jogging with jog keys and touching displays all coordinate systems allowing you to change systems
7. Jog Key Labels- displays the current selected coordinate system or axis and touching causes the selected kinematics group to be displayed
8. Program Override
9. Jog Override
10. Button Bar- change dynamically and always refer to the window that is currently active in the smartHMI. Within this bar is the EDIT button which can be used to call numerous commands relating to the navigator
11. Clock
12. WorkVisual Icon- touching causes the active project and the OPEN button to be displayed. OPEN takes you to the Project Management window



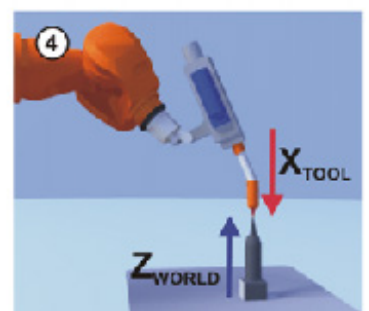
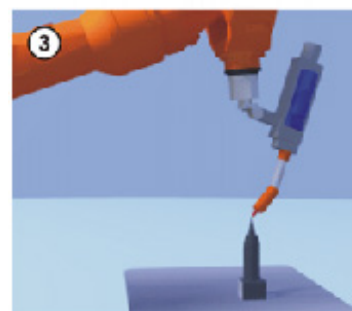
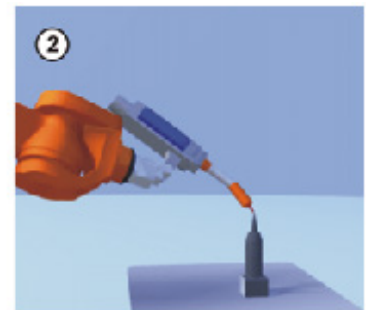
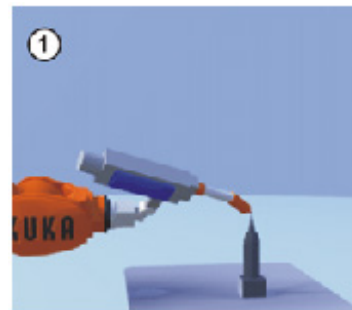


In this assignment, you will review some basic knowledge of KUKA Robotics, including safety, work envelope, work cell, primary components, screen displays, axis-specific motion, coordinate systems, and tools. Now, we will continue with how to teach a new tool for a new project with the KUKA robot arm system. **Teaching a tool to an industrial KUKA robot arm is how you set an accurate tool touch point (TCP) to generate tool**

**paths to follow an orientation so the robot arm knows where and how to move. In this assignment you will set a TCP. During this process it is ideal to turn the movement increments down to get an accurate as possible TCP. The tool to be calibrated is mounted on the mounting flange and should be operating in mode T1. For this particular method the four points need to be far apart as possible and avoid them being more than 180 degrees apart.**

## Teaching A Tool: XYZ 4-Point

1. In the main menu, select Start-up > Calibrate > Tool > XYZ 4-point.
2. Assign a number and a name for the tool to be calibrated. Confirm with Next.
3. Move the TCP to a reference point. Press Calibrate. Answer the request for confirmation with Yes.
4. Move the TCP to the reference point from a different direction. Press Calibrate. Answer the request for confirmation with Yes.
5. Repeat step 4 twice.
6. Enter the payload data. (This step can be skipped if the payload data are entered separately instead.) (>>> 5.8.3 "Entering payload data" Page 134)
7. Confirm with Next.
8. If required, coordinates and orientation of the calibrated points can be displayed in increments and degrees (relative to the FLANGE coordinate system). For this, press Meas. points. Then return to the previous view by pressing Back.
9. Either: press Save and then close the window via the Close icon.

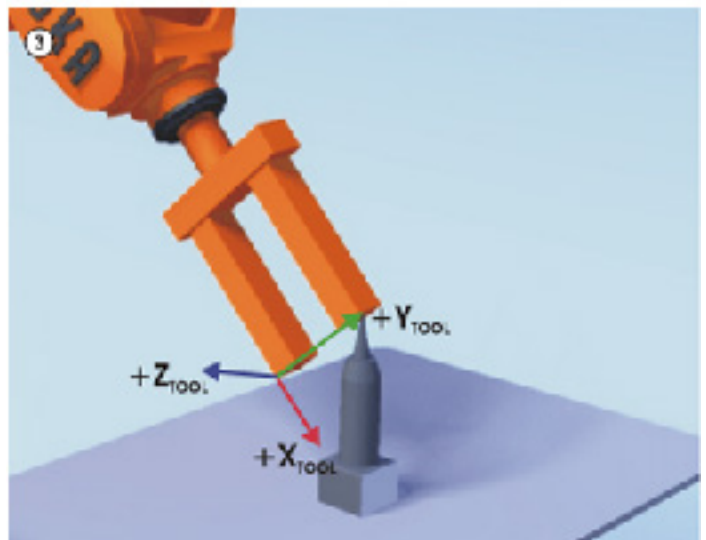
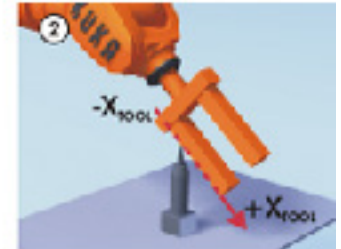


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tool paths to follow an orientation so the robot arm knows where and how to move. In this assignment you will set a TCP. During this process it is ideal to turn the movement increments down to get as accurate as possible TCP. Next this method is used if it is necessary to define the axis directions with particular precision, a gripper tool as an example. The TCP of the tool has already been measured and should be operating in the mode T1.

## Teaching A Tool: ABC 2-point

1. In the main menu, select Start-up > Calibrate > Tool > ABC 2-point.
2. Enter the number of the mounted tool. Confirm with Next.
3. Move the TCP to any reference point. Press Calibrate. Answer the request for confirmation with Yes.
4. Move the tool so that the reference point on the X axis has a negative X value (i.e. move against the tool direction). Press Calibrate. Answer the request for confirmation with Yes.
5. Move the tool so that the reference point in the XY plane has a negative Y value. Press Calibrate. Answer the request for confirmation with Yes.
6. Enter the payload data. (This step can be skipped if the payload data are entered separately instead.) (>>> 5.8.3 "Entering payload data" Page 134)
7. Confirm with Next.
8. If required, coordinates and orientation of the calibrated points can be displayed in increments and degrees (relative to the FLANGE coordinate system). For this, press Meas. points. Then return to the previous view by pressing Back.
9. Press Save.



In this assignment, you will review some basic knowledge of KUKA Robotics, including safety, work envelope, work cell, primary components, screen displays, axis-specific motion, coordinate systems, and tools. Now, we will continue with how to teach a new base for a new project with the KUKA robot arm system.

Teaching a base to an industrial KUKA robot arm is how you set a plane for your tool paths to follow an orientation so the robot arm knows where and how to move. Before this step you will need to make sure that you have your tool defined and your TCP set. During base calibration, the user assigns a Cartesian coordinate system (BASE coordinate system) to a work surface or the workpiece. The BASE coordinate system has its origin at a user-defined point.

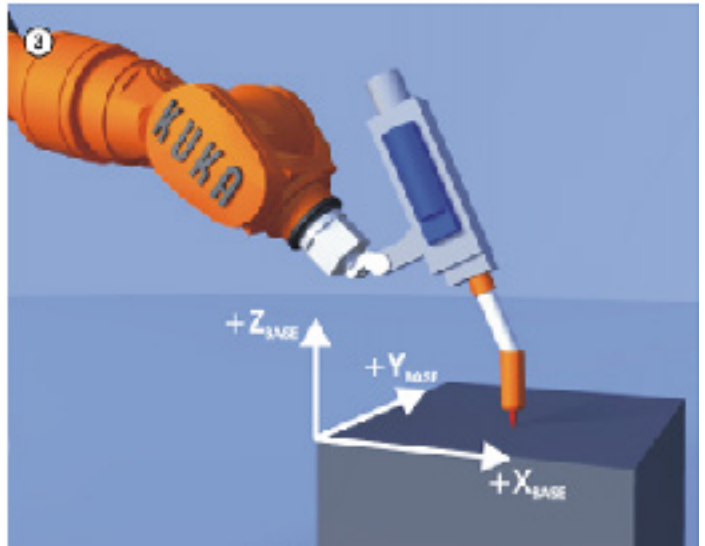
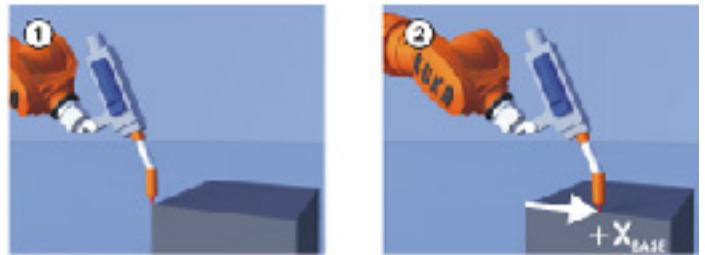
## Teaching A Base: 3- Point

### Advantages

The TCP can be jogged along the edges of the work surface or workpiece.

Points can be taught relative to the base. If it is necessary to offset the base, e.g. because the work surface has been offset, the points move with it and do not need to be retaught.

1. In the main menu, select Start-up > Calibrate > Base > ABC 3-point.
2. Assign a number and a name for the base. Confirm with Next.
3. Enter the number of the mounted tool. Confirm with Next.
4. Move the TCP to the origin of the new base. Press Calibrate. Answer the request for confirmation with Yes.
5. Move the TCP to a point on the positive X axis of the new base. Press Calibrate. Answer the request for confirmation with Yes.
6. Move the TCP to a point in the XY plane with a positive Y value. Press Calibrate. Answer the request for confirmation with Yes.
7. If required, coordinates and orientation of the calibrated points can be displayed in increments and degrees (relative to the FLANGE coordinate system). For this, press Meas. points. Then return to the previous view by pressing Back.
8. Press Save.



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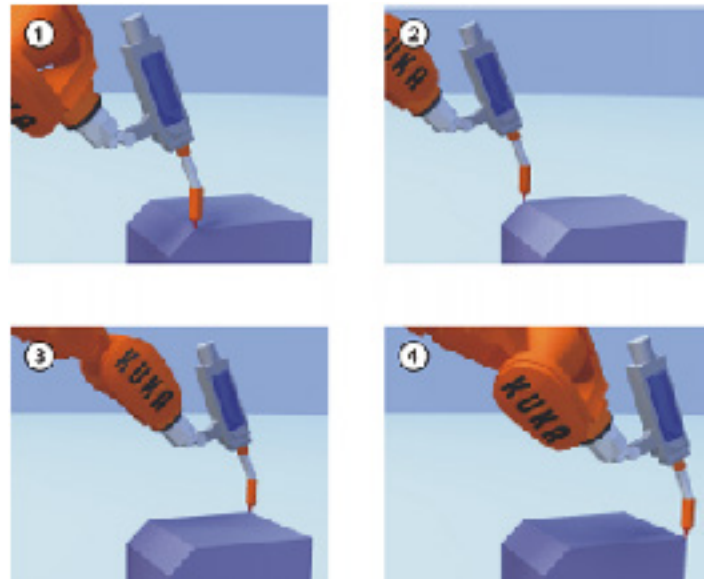
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## Teaching A Base: Indirect

The indirect method is used if it is not possible to move to the origin of the base, e.g. because it is inside a workpiece or outside the workspace of the robot.

The TCP is moved to 4 points in the base, the coordinates of which must be known. The robot controller calculates the base from these points.

1. In the main menu, select Start-up > Calibrate > Base > Indirect.
2. Assign a number and a name for the base. Confirm with Next.
3. Enter the number of the mounted tool. Confirm with Next.
4. Enter the coordinates of a known point in the new base and move the TCP to this point. Press Calibrate. Answer the request for confirmation with Yes.
5. Repeat step 4 three times.
6. If required, coordinates and orientation of the calibrated points can be displayed in increments and degrees (relative to the FLANGE coordinate system). For this, press Meas. points. Then return to the previous view by pressing Back.
7. Press Save.





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Having access and operating this equipment and utilizing a shared space means that there needs to be a level of respect for the technology but also others that may be using the shared space. The space is relatively small and poses a lot of risks if cluttered along with a lose of efficiency of the space. Follow these simple post operation practices to continue to be allowed access to this equipment and space.

## Post Operation Practices

Before shutting down the machine at the end of a session:

1. Remove any tooling from the robot and store it properly.
2. Move arm in a manner that keeps the walkway clear to maintain CNC router material access.
3. Neatly wrap all cords.
4. Place the teach pendant in its holder.
5. Make sure any high voltage power is off at the breaker.
6. Clean up your personal items and remove your fixtures form the lab.
7. Return any borrowed equipment.
8. Make sure to sweep the area if necessary.
9. Make sure to fill out the housekeeping checklist.
10. Make sure to turn all the lights off.
11. Make sure that all doors are locked upon exiting.

