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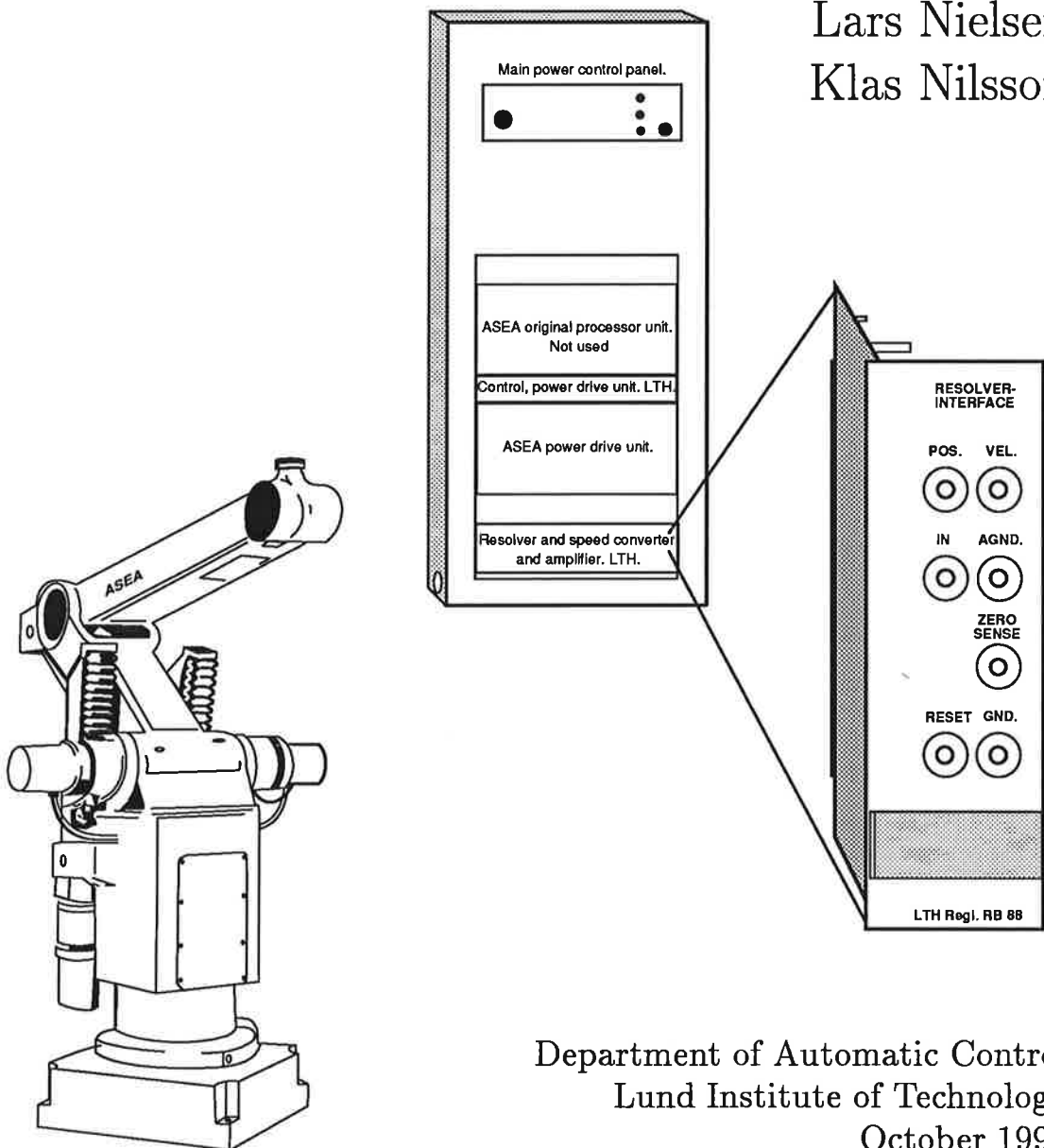
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Reconfiguring an ASEA IRB-6 Robot System for Control Experiments

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Lund Institute of Technology
October 1990

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<i>Title and subtitle</i> Reconfiguring an ASEA IRB-6 Robot System for Control Experiments			
<i>Abstract</i> <p>An industrial robot system, the ASEA IRB-6/2, has been modified for laboratory use. The modification of the robot system was approached with the goal to keep the mechanics and the power electronics, and also as much as possible of the existing safety system, and only add parts necessary to create general interfaces to our own computers. The closed structure of the original control system has been opened up, providing the possibility for the user to implement the entire control. The motor drives of the robot are still used. The original analog speed control of the joints can be used, or other modes of operation can be selected joint-wise on the new interface designed. A new sensor interface for reading the resolver signals has been put in parallel with the original one. The new sensor interface has analog velocity and position outputs for each joint. The position signal is also available in digital form via a 16-bit bus. The result is that the robot is now equipped with general interfaces so computer systems with standard interfaces can be used. The system has been used for both research and teaching, implementing the control in computers like IBM PC/AT or a VME-based board computer system connected to a Sun workstation.</p>			
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<i>Security classification</i>			

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1. Introduction

An industrial robot, like the ASEA IRB-6, is usually delivered with its control cabinet, control system, and operator's interface. These systems are cost optimized and normally forms a closed and rigid structure. Therefore, there are a number of design considerations if we are going to modify a system and to make it flexible and useful both for research and teaching. The objectives of such a modification could differ, but our goals are to do control experiments in a wide sense. The Robot Laboratory group within the Department of Automatic Control, Lund, Sweden, has its interests in control servos for robot control, and other aspects particular to robots such as path following, sensor integration, and robot programming. Aspects of mechanical design and design of power drive units are thus not major interests.

The first design decision, in modifying the robot system, is where to open up the system. With our interests as a background it is natural to keep the mechanics and the power drive units. The original control computer within the control cabinet is inaccessible for programming so it has to be left out. As a consequence, sensor interfaces originally being a part of the control computer has to be designed. However, the original system features a number of safety functions that are desirable to keep. These are e.g. emergency breaks that are essential for human protection, and there are also robot protections e.g. against overloading and current limitations.

The resulting system has been used for both research and teaching. As will be described in the following, the robot is now equipped with general interfaces so computer systems with standard AD and DA converters can be used. We have so far used both a system based on IBM PC/AT and a system based on a Sun Sparc work station plus a VME-based board computer for the direct computer control of our robot. The robot system with the modifications made, and with the door of the control cabinet removed, is shown below.

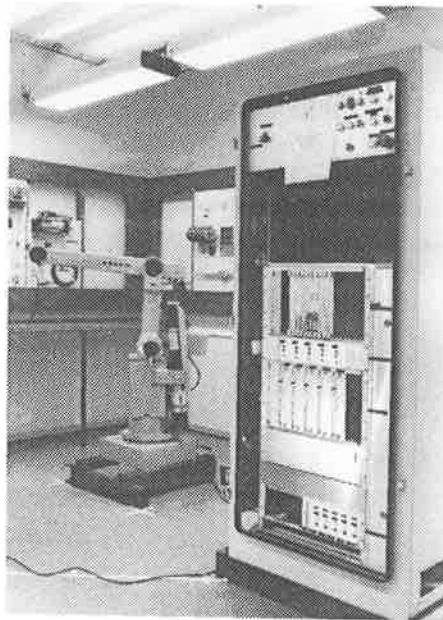


Figure 1.1 The modified robot system in our lab.

2. Overview of solution

The main goal of the reconfiguration of the control system is to be able to do experiments in control, where the experiments can be done on several levels ranging from basic servo experiments to overall programming of the robot functions. The modification of the robot system was approached with the goal to keep the mechanics and the power electronics, and also as much as possible of the existing safety system, and only add parts necessary to create general interfaces to our own computers. The descriptions and drawings of the modifications included in this report, together with manuals available from ABB Robotics, form a complete description on how to do the reconfigurations.

The idea of our solution is captured on the cover of this report, where we try to illustrate that we connect to the robot only via our own interfaces. An overview of the resulting design can be seen in Figure 2.1. The original control

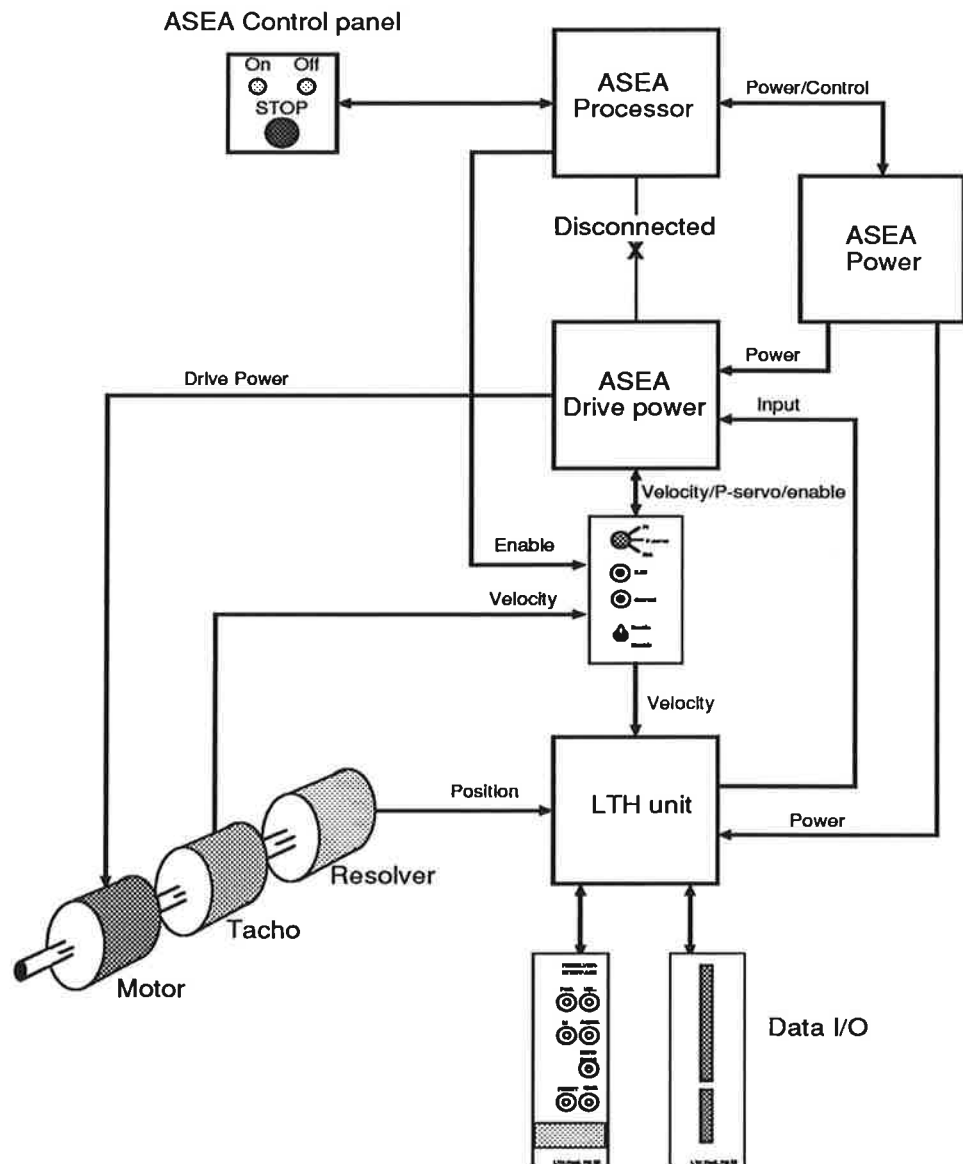


Figure 2.1 Overview of modifications. Only one axis shown for clarity.

computer is kept only because it relays some functions in the safety system. However, the original functions to take care of the measurements are not used. Instead, we have built our own sensor interface, and as will be clear later, we have done it in a way that makes it possible to keep the sensors and cables already available inside the robot itself. The sensor system for measurements of robot joint angles is based on resolvers. Our solution principle is to drive and read the resolvers in our own hardware based on existing commercial chips for resolver-to-digital conversion. The principle solution can be seen as part of Figure 2.1. A more detailed but still principle solution of the main module added can be seen in Figure 2.2, and the front panel of the new analog interface is shown in Figure 2.4.

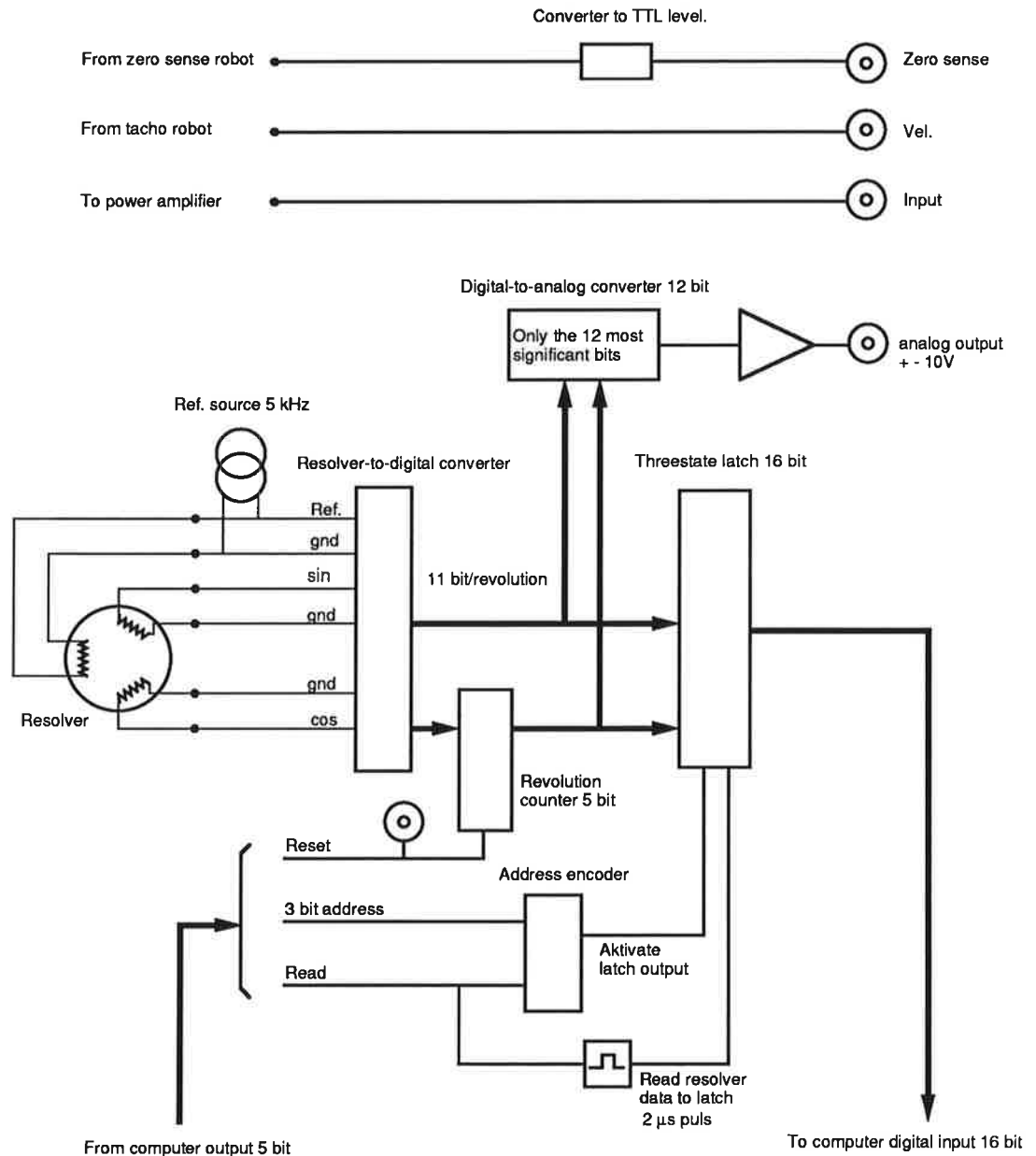


Figure 2.2 Principle solution of the resolver measurement system.

The resolver signals are not going to the ASEA controller any more, and therefore some signals on the front of the ASEA resolver interface are connected together to prevent an error detection. In this way, the ASEA con-

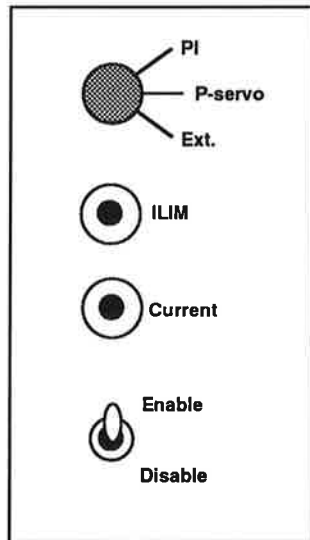


Figure 2.3 The "LTH front panel" for one ASEA drive unit.

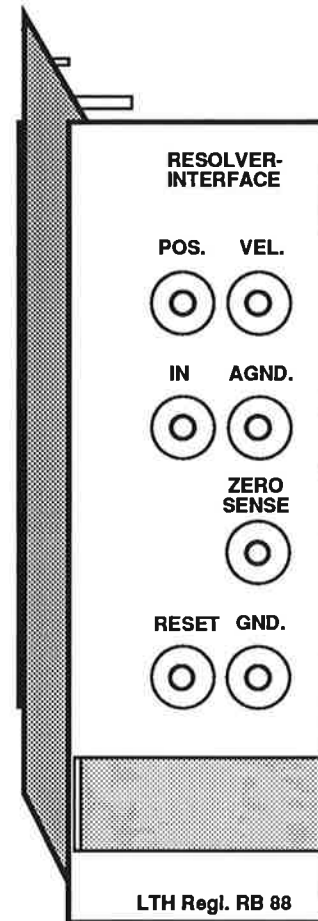


Figure 2.4 The new analog sensor interface for one joint.

troller believes that the robot is in zero-position, even when moving. Refer to Chapter 3 for a description.

The principle solution for driving the motors is shown in Figure 2.1. The original position controller, as well as the original resolver measurement system, is implemented on the ASEA processor unit and can not be accessed. When not using the original position controller, the user can (and must) implement the position control. The user can select to use the original analog PI-speed-control available on the drive units. In this case it is sufficient to implement an external P-regulator for position control.

Being interested in control engineering, it is desirable to have full access to the speed control. We have implemented such possibilities by overriding the analog PI-control using the compliant control capability of original controllers (called P-servo or soft-servo by ASEA) in a totally different way. As a first such alternative it is possible to select to use a built-in analog speed control of pure P-type (for good disturbance rejection), and to implement controllers e.g. for active damping externally, i.e. in the user's own system. Another selectable alternative for the user is to implement the entire speed (and position) control externally. The reference (IN in Figure 2.4 which is the Input in Figure 2.2) then acts as a torque reference. These two added possibilities for control experiments have been implemented utilizing knowledge about the internal structure of the original control system and has thus not required any modifications of the internal hardware. The wanted mode of operation is se-

lected for each axis via the rotary switch on the top of the "LTH front panel" to the ASEA drive unit, see Figure 2.3. As indicated in Figure 2.3, each drive unit can also be disabled by the use of the Enable switch.

In conclusion, major problems were to find the right points to cut into the system while still keeping some of the functions available, and then to design and implement the additions needed. If the modifications are carefully done, the system can easily be converted back to its original shape.

3. The modified control system

The modifications done to the robot system itself will now be described. The original robot was a standard ASEA IRB6 robot with the control system S2. The modifications related to the sensors are simple. They consist of cutting the wires and replacing the sensor system with our own. The situation concerning the drive units is a bit more complicated since it is desirable to keep major parts of the system. To keep the safety system we have to create an environment where the original control computer sees consistent measurements and control signals. This implies some strapping of signals and also that some of the cut wires have to be given certain values.

3.1 Wiring and cables

The resolver cables were disconnected at the robot base, i.e., at connectors X3, X4, and X5. Refer to ASEA manuals and to Appendix A for details (the names of signals, here and in the following, are the same as used by ASEA). New connectors, one for each joint, were then built on to the robot base, see Figure 3.1, and the resolver cables were connected. The tachometer signals and the zero position switch signals are still available in the original system, but also goes to the new connectors.

3.2 Control of power drive units

As described in Chapter 2, each motor drive unit can be used in three different modes: Internal velocity control of PI-type, Internal velocity control of P-type,

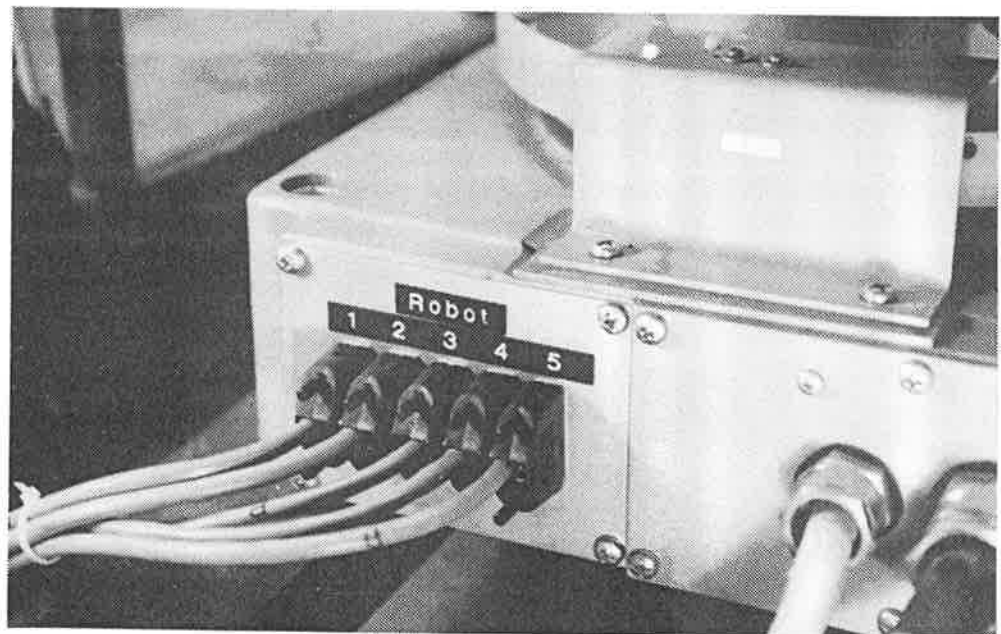


Figure 3.1 Connections to the five joints.

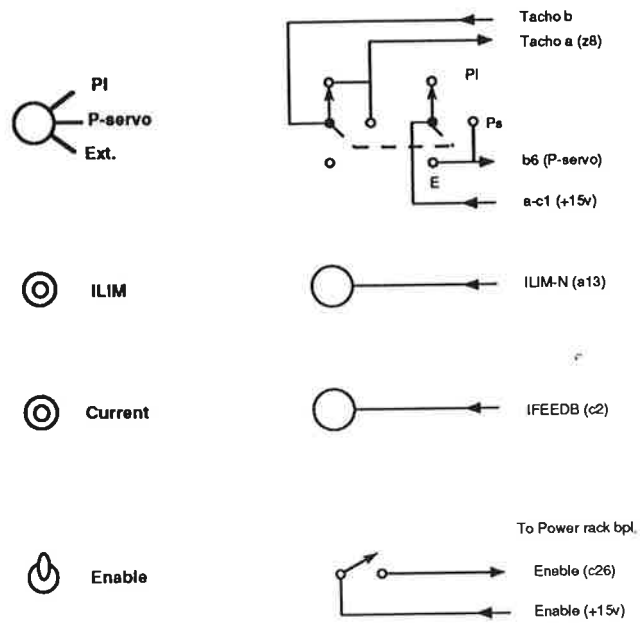


Figure 3.2 Front panel and signals connected.

and external velocity control. The mode is selected by the switches on the "LTH front panel", where also the signals "ILIM" and "Current" are made available, see Figure 2.3 for front view and Figure 3.2 for implementation. We have located each of these panels above the corresponding drive unit as shown in Figure 3.3.

The ILIM signal is a digital output going low when the drive unit for that joint has reached its current (i.e., torque) limit. A voltage proportional to the actual current (torque) is made available as the "Current" signal, which is useful for advanced position or path control when the analog speed control is used.

Each joint can also be disabled using the enable switch. The implementation shown in Figure 3.2 refers to ASEA's notion for the signals. Physically

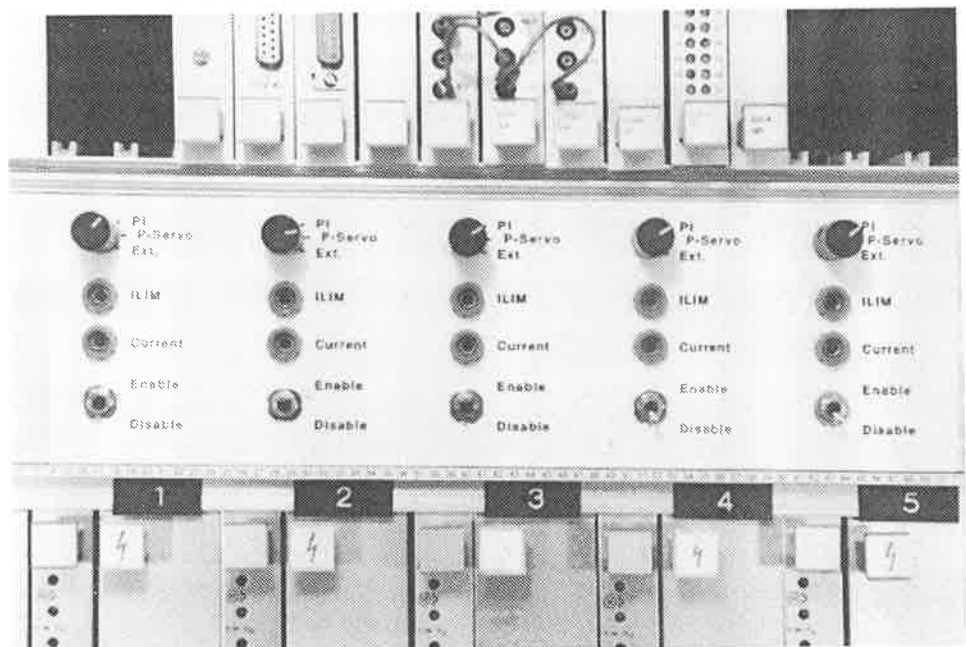


Figure 3.3 Location of front panels to the drive units.

the signals are reached on the backplane as shown in Figure 3.4. Refer to Appendix B for further details. Sensor signals are not effected by disabling the drive unit of the joint, only the motor is made powerless.

To use the P-servo (see Figure 3.2) mode, it is normally required that the ASEA-system is equipped with compliant control (also called soft-servo by ASEA). In our system we have the oldest version of the drive units, which have been modified according to Appendix C to be the same as the newer units with compliant control. It is possible that later versions of the drive units without compliant control requires even more changes. Instead, it is possible to buy the soft-servo option.

3.3 Fooling the original control computer

Because the resolver measurement have been modified, as described in Section 3.1 and Chapter 2, we have to supply new signals to the ASEA controller. By using the sinus feed for the resolvers as the signal coming from the resolver, the control computer gets consistent measurement for position $\equiv 0$. This is done by plugging some cables into connections available for fault-finding according to:

- Connect the 0V of board DSQC 103 to 0V on the DSQC 104 boards.
- Connect the SIN-signal of board DSQC 103 to FB1, FB2, and FB3 on the DSQC 104 boards.

Figure 3.5 is a picture of the connections.

Some modifications of the connections to the drive units are also required. The velocity references from the original control computer have to be cut because we use our own reference input (IN in figure 2.4). The torque limit indication (ILIM, see section 3.2) signals going from the drive units to the DSQC-boards have to be put to +15V. The latter change is to prevent jam-error detection (see next section). Details are shown in Appendix D.

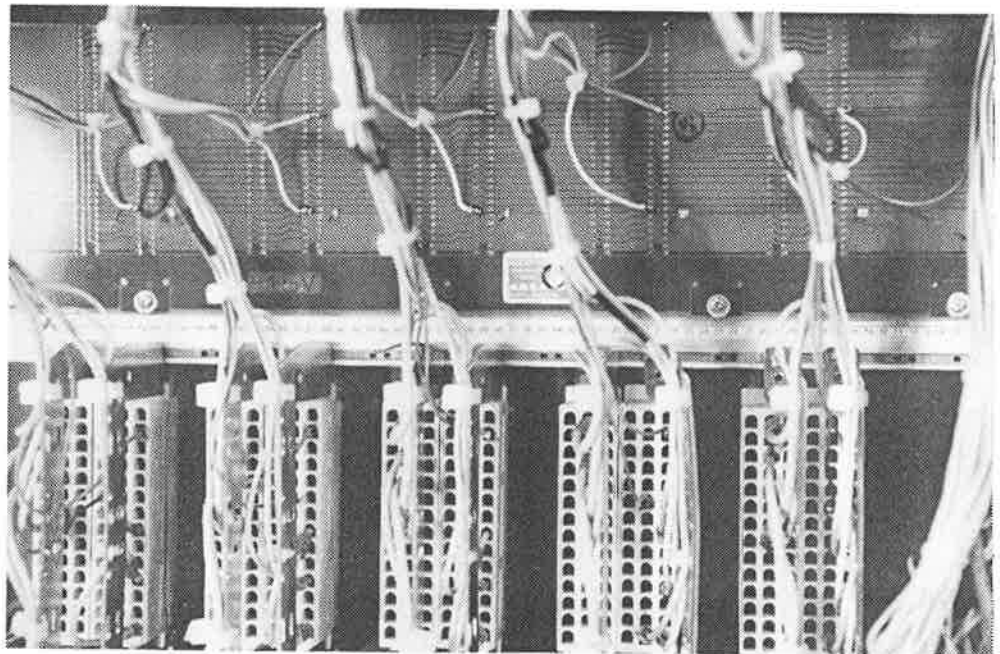


Figure 3.4 The backplane of the ASEA drive units where signals have been changed and added.

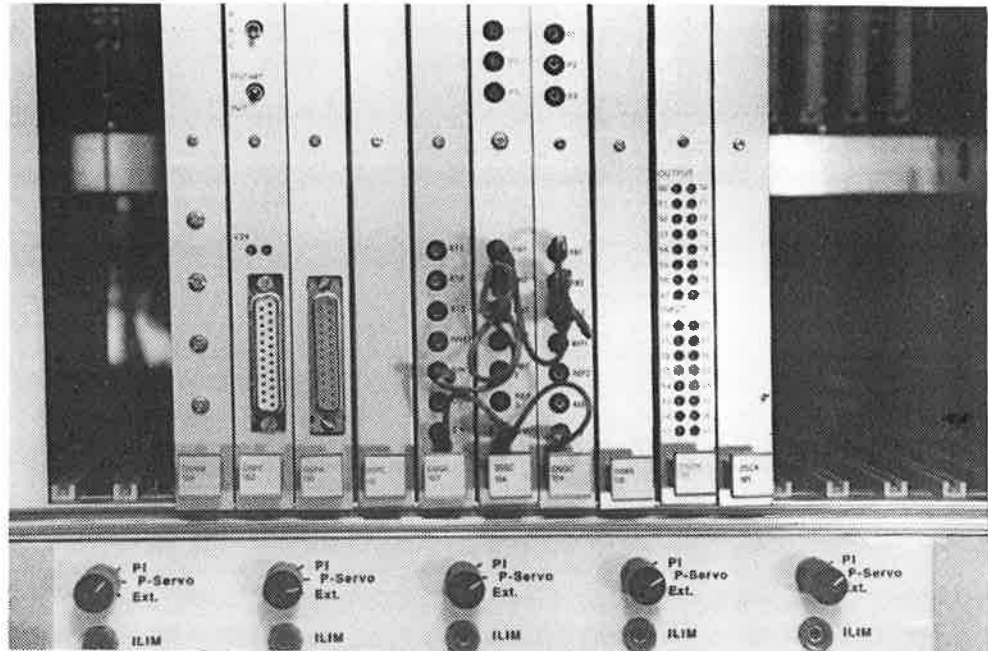


Figure 3.5 Original control computers and IO-boards, which are fooled by the extra cables in the middle of the picture.

3.4 Alarm and safety system

The emergency stop buttons and loops in the system still work. This means that all possible equipment for personnel safety (gates, light-beams) can be used as usually. The thermal overload detection for the motors also functions. The (in software) built in jam-error detection is, however, by-passed, but can be implemented as a detection of (almost) zero velocity with max torque (see ILIM above) for 0.2 seconds.

3.5 Teach pendant

After the modifications made, only the emergency stop of the teach pendant (or programming unit) can be used. Trying to move or program the robot with the original system will result in error messages.

4. The new sensor interface

The new resolver interface is implemented as one board for each joint. A front view of the board (called the LTH unit) has been shown in Figure 2.4. The design of the boards as well as the bus connecting them together is the subject of this chapter.

4.1 The sensor interface rack

The sensor interface modules have been placed in a rack below the drive units and rectifier. A front view, and a back view, of the rack is shown in Appendix E, as well as a side view of one resolver to digital converter module. Drawings of the back-plane, power supply, and the connections to the robot are all in Appendix F.

4.2 R/D-conversion

The resolvers are driven by a 5 kHz triangle wave. The circuit 2S80JD from Analog Devices is used for resolver to digital conversion (RDC). It gives a digital value of the angle within one motor revolution in 12 bits. Each joint has its own resolver interface from which an analog position signal is available. The digital position value can also be read directly via the digital I/O module, which implements a parallel bus as shown in Appendix G. Each resolver interface is addressed as shown in Appendix H.

4.3 Design of the RDC module

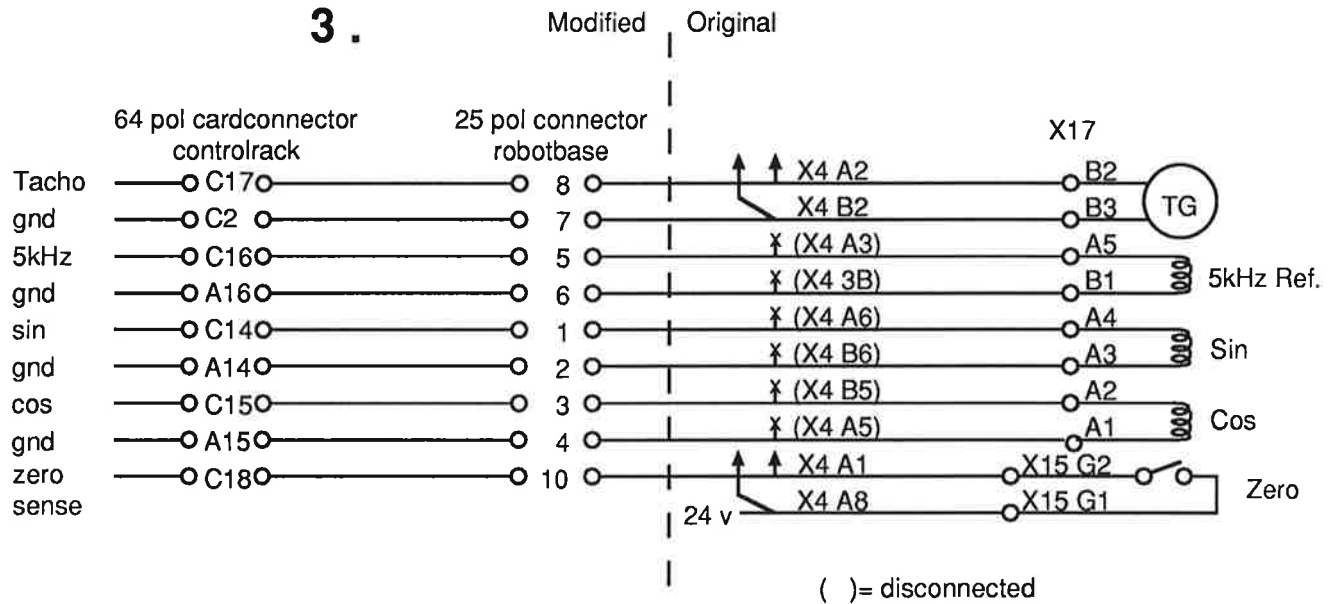
A front view of the Resolver to Digital Converter module is shown in Figure 2.4, and the internal design will now be described. To provide analog position signals covering a fairly large part of the robot's working range, a counter is added to the 12 bits from the RDC. This counter has 8 bits, of which 5 are used. Of these totally 17 bits representing the motor angle, the most significant 12 bits are converted to an analog position (POS in Figure 2.4), signal in the range $\pm 10V$, useful basically for test purposes. The most significant 16 bits (could easily be modified to be the least significant 16 bits if higher resolution is needed) of the 17 bits are connected to the bus via a three-state buffer. To read the value, a three bit address code and a global read signal have to be set via the digital I/O interface. Refer to Figure 2.1, 2.2, and to Appendix H for timing.

The signals from the so called sync-switches on the robot also goes to the RDC-module, where they are made available as the zero-sense signals used for initializing the robot to the zero position. To synchronize the robot with the measurement system, each joint has to be moved (under speed control) in the direction of a change for the zero-sense. When this occurs, a pulse input on the reset signal has to be generated, which resets the internal counter.

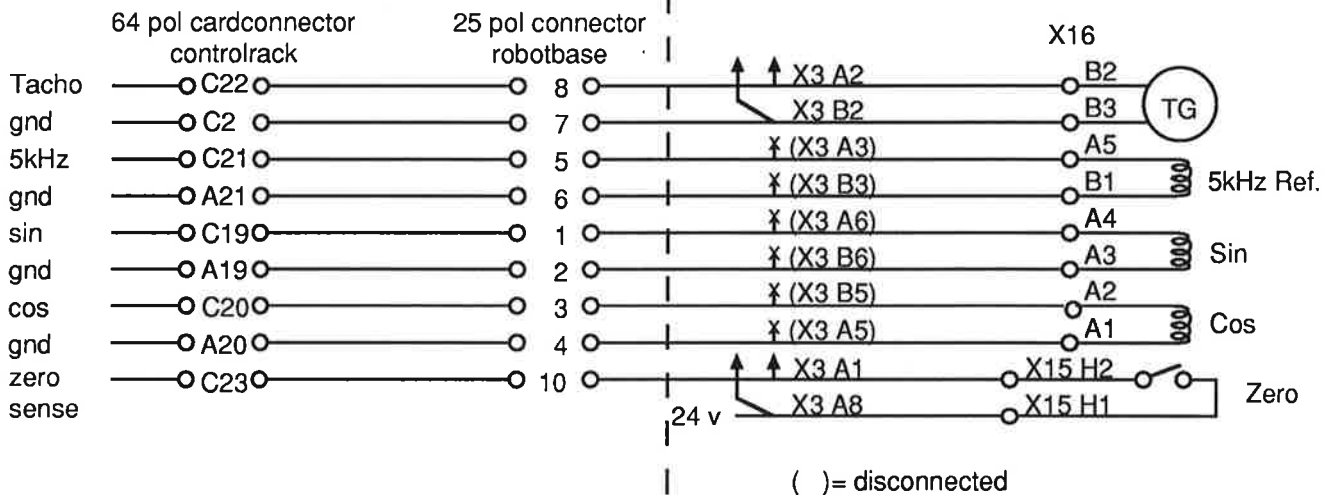
Two more signals are available on the RDC-module. First the reference input IN which is in the range $\pm 10V$ corresponding to ± 3000 rpm if PI or P-servo mode is used, and to $\pm 15A$ motor current if the Ext mode is used. Secondly the tachometer signal is output in the range $\pm 9V$ approximately corresponding to ± 3000 rpm. It is a minor modification to use the velocity signal from the RDC-chip instead, if control without use of a speed sensor is of interest. The complete circuit diagram can be found in Appendix I.

LTH Reglerteknik Lund	ASEA Robot modification Robot base 1	Asea Int.S Robotbase mod.
		900319 RB
		Rev 900517 RB

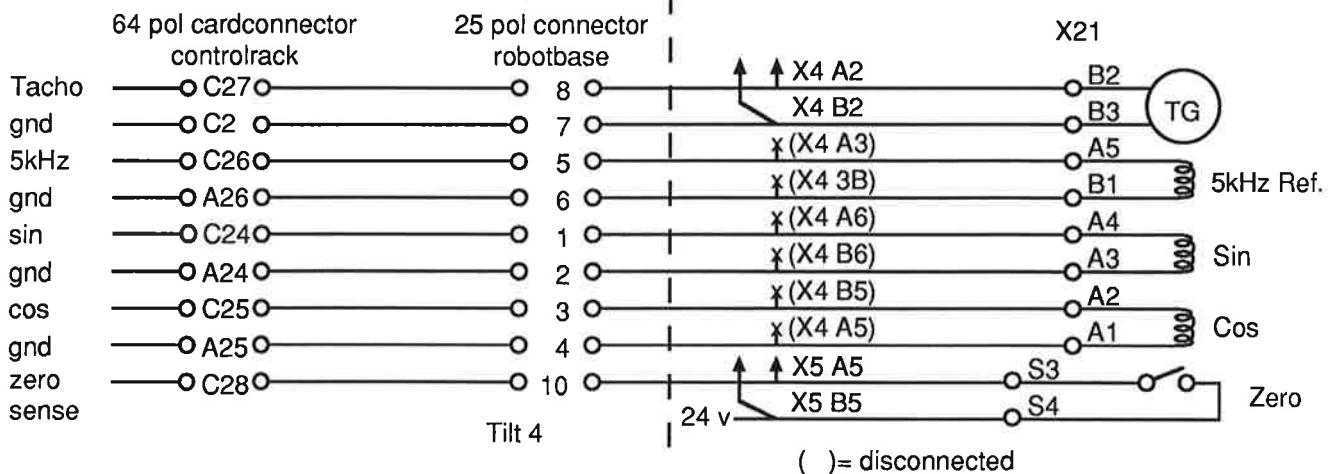
3.



2.

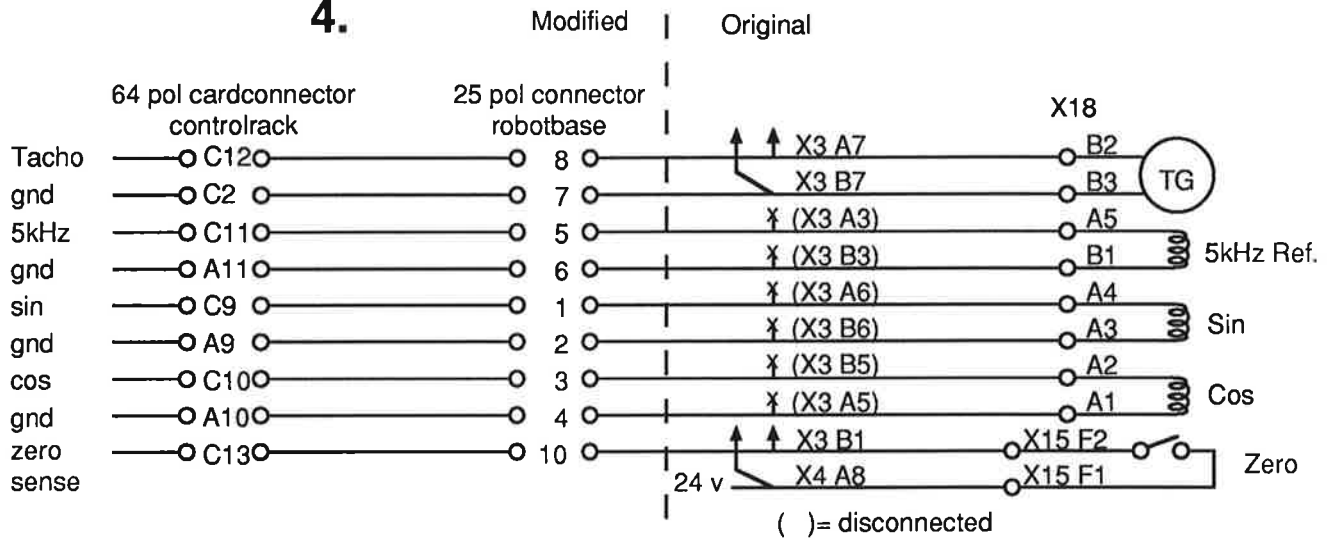


1.

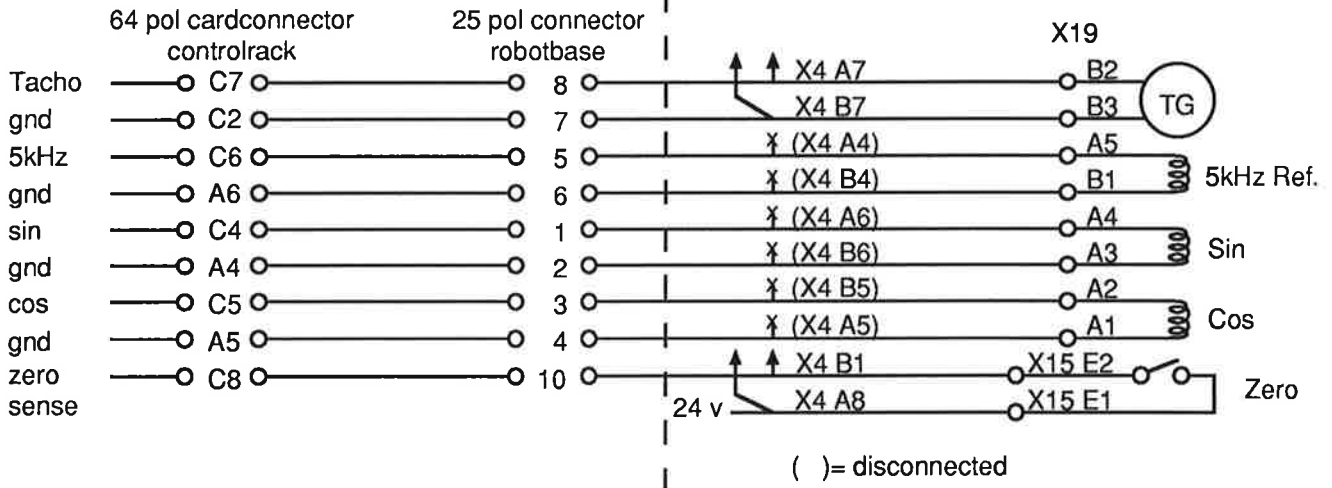


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		Rev 900517 RB

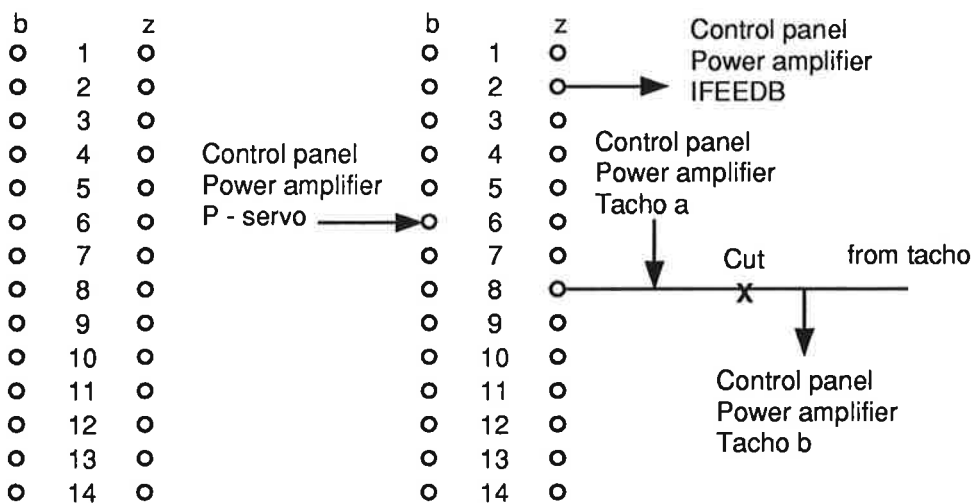
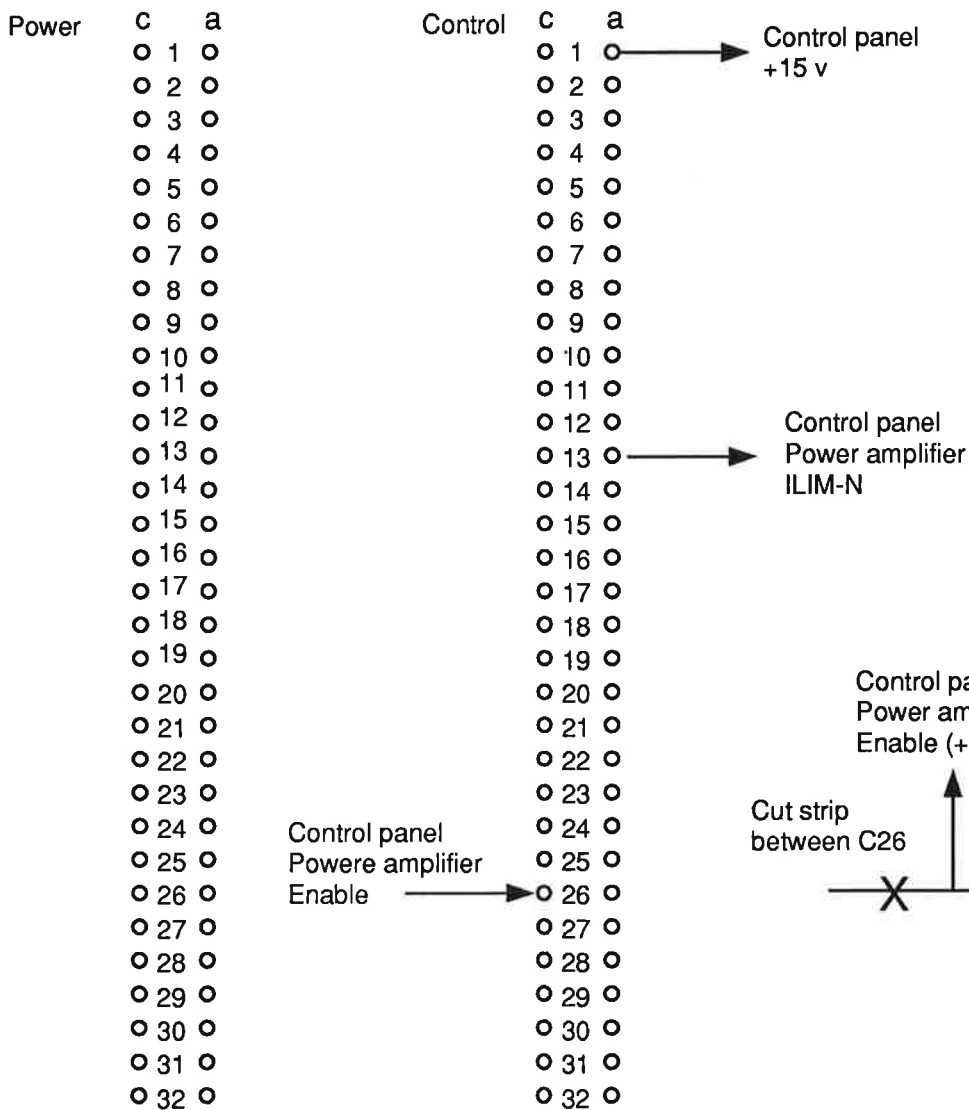
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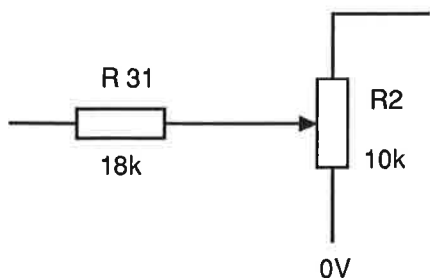
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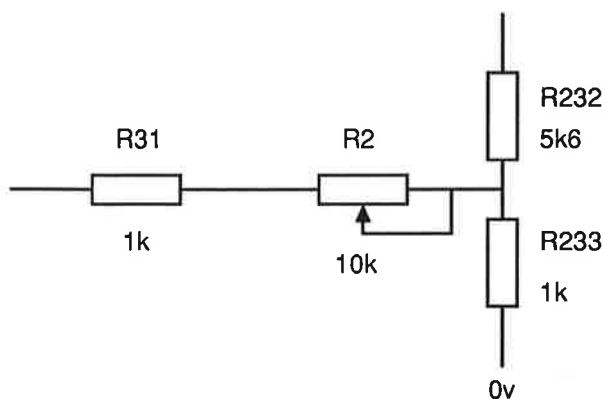
LTH Reglerteknik Lund	ASEA Robot Modification ASEA drive power Backplane	Asea int.S Power rackbpl
		900328 RB



LTH Reglerteknik Lund	ASEA Robot Modification ASEA drive power YYT 102 P-SERVO	Asea Int. mod. contrl. unit
		900614 RB
		Rev. 901019 RB



Old



New

Modification from old to new version

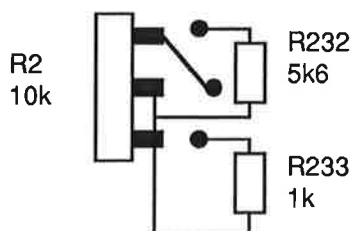
$$R27 = R29 = 47k$$

$$\text{gain} = \frac{1}{R27+R29} \left(R2 \left(1 + \frac{R232}{R233} \right) + R31 + \frac{R31 * R232}{R233} + R232 \right)$$

$$R2 = 0 \quad \text{gain} = 0,3$$

$$R2 = 10 \text{ k} \quad \text{gain} = 1$$

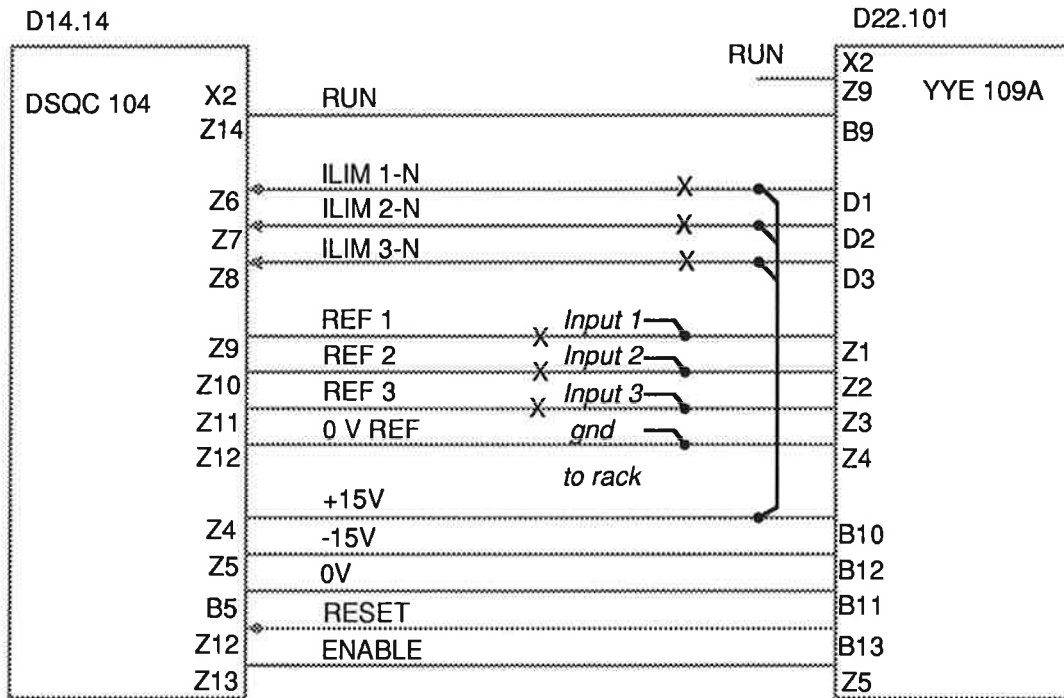
Cut pins from pot R2 modifie as figure .
 Change R31 from 18k to 1k



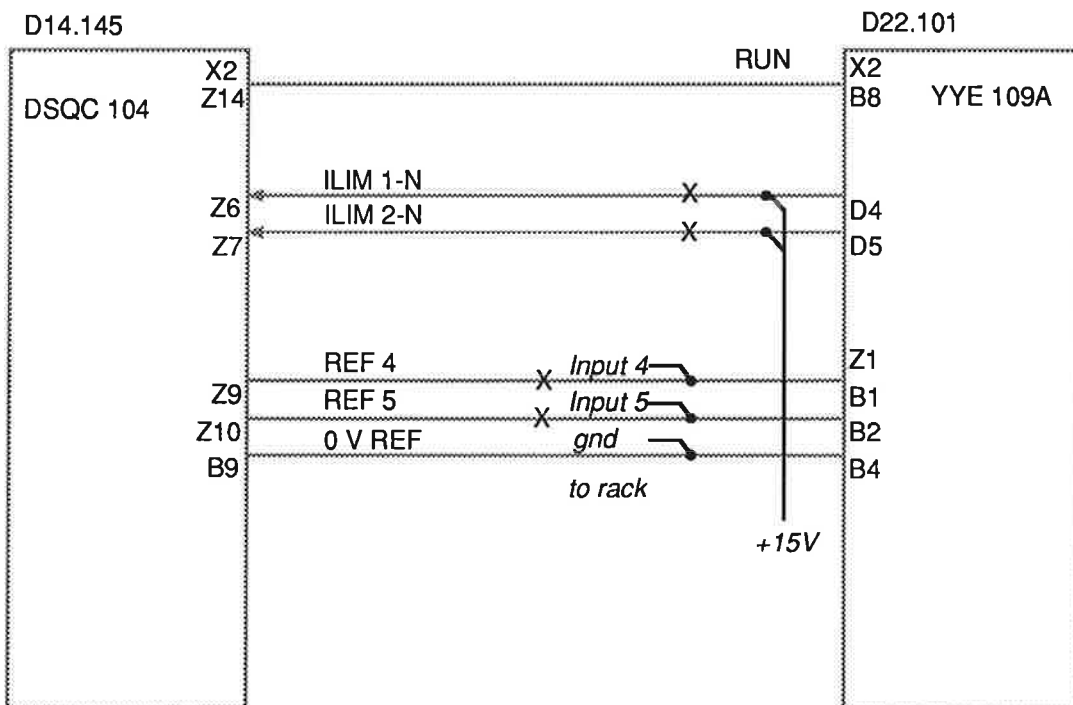
LTH Reglerteknik Lund	ASEA Robot Modification ASEA drive power Backplane	Asea Int.S processor mod. 1
		900319 RB

X= Disconnected

———— = modified



ASEA drawing 6704 100-BCA 17



ASEA drawing 6704 100-BCA 19

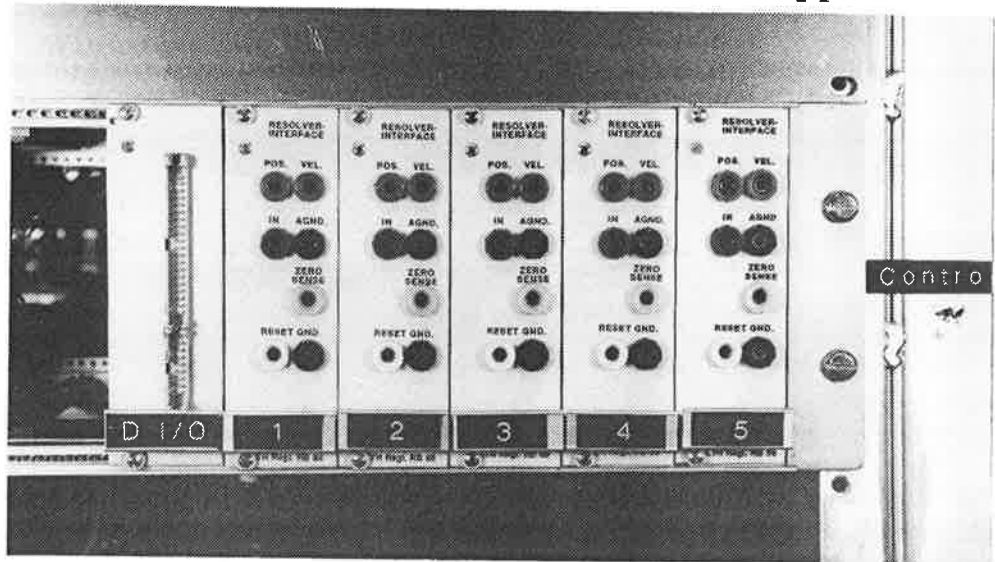


Figure E.1 Front view of the sensor interface rack.

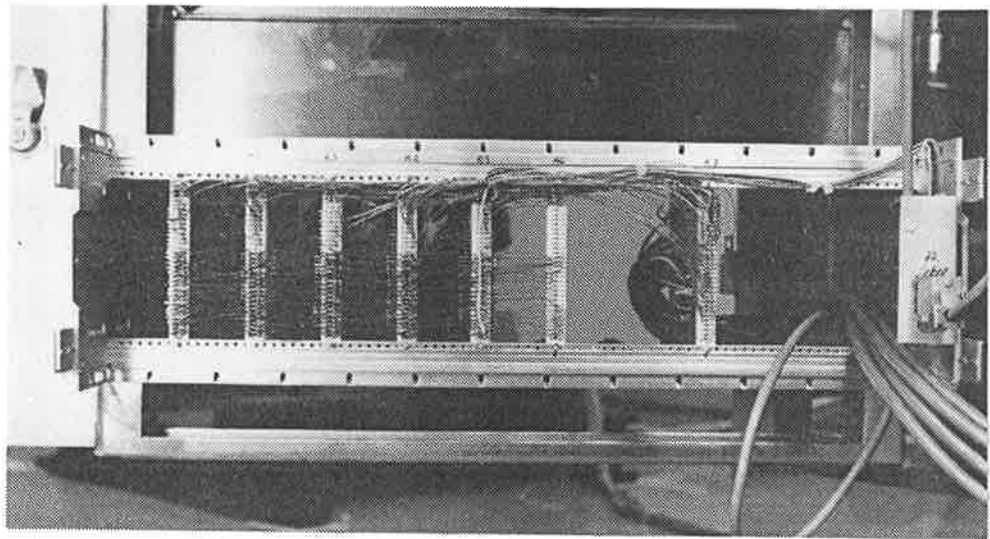


Figure E.2 Back view of the sensor interface rack.

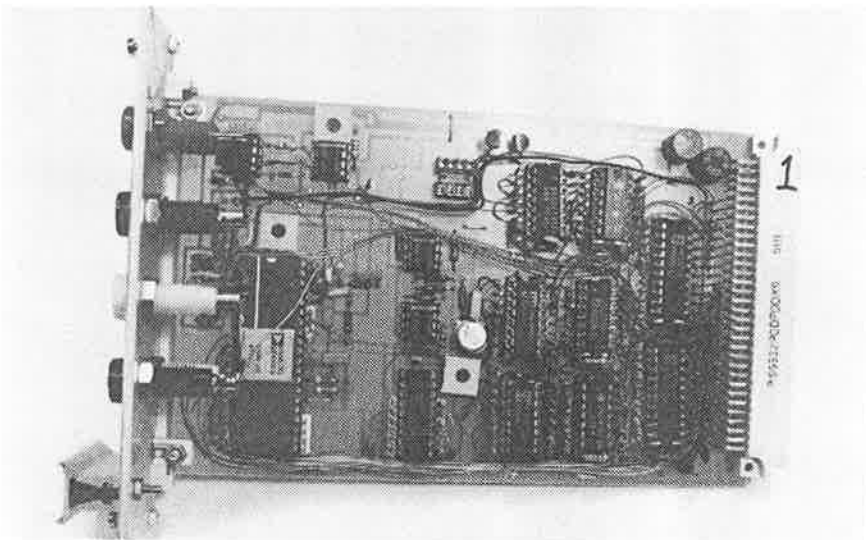
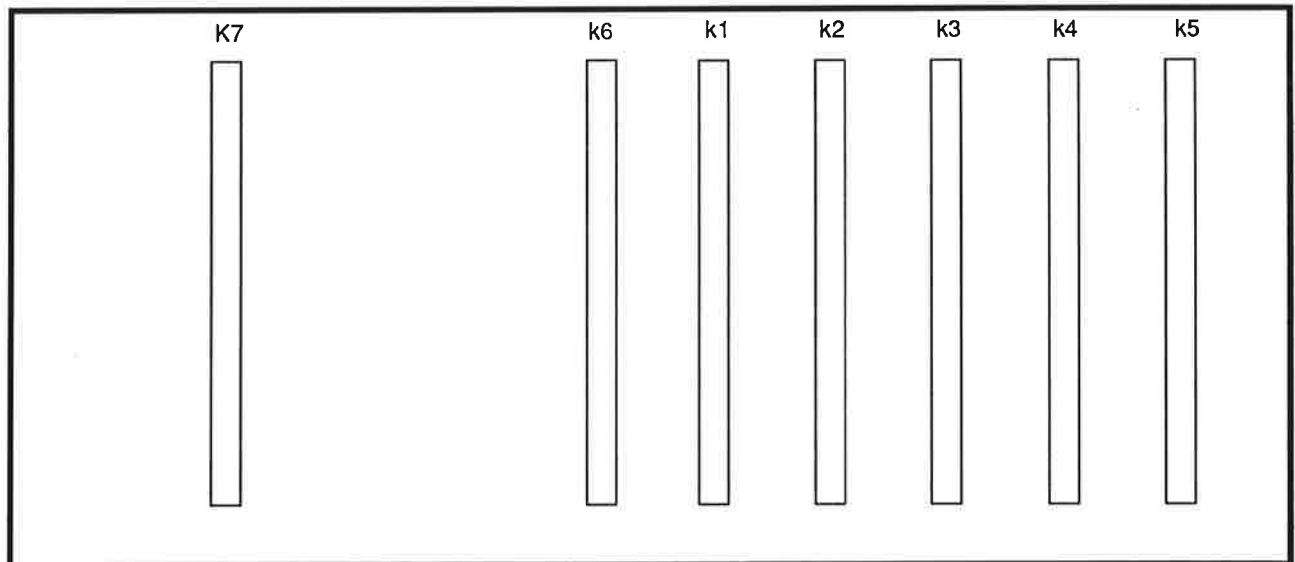


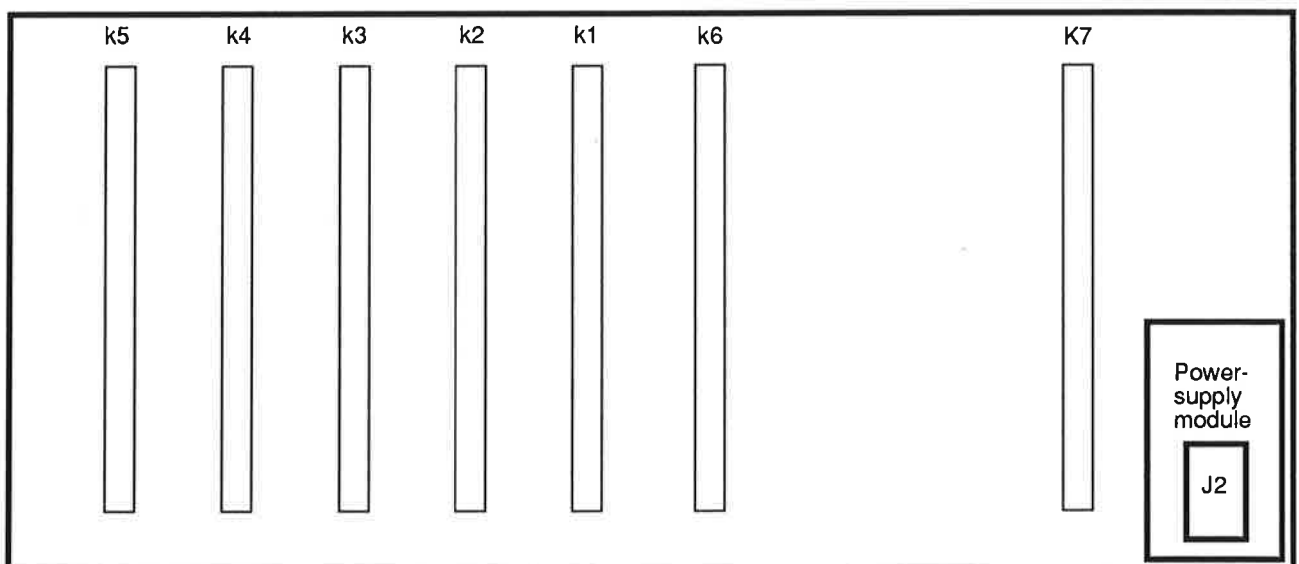
Figure E.3 Side view of one interface module (LTH module).

LTH Reglerteknik Lund	ASEA Robot LTH unit Backplane	ASEA Int.S rack f and b
		900323 RB
		Rev. 900423 RB

Front view

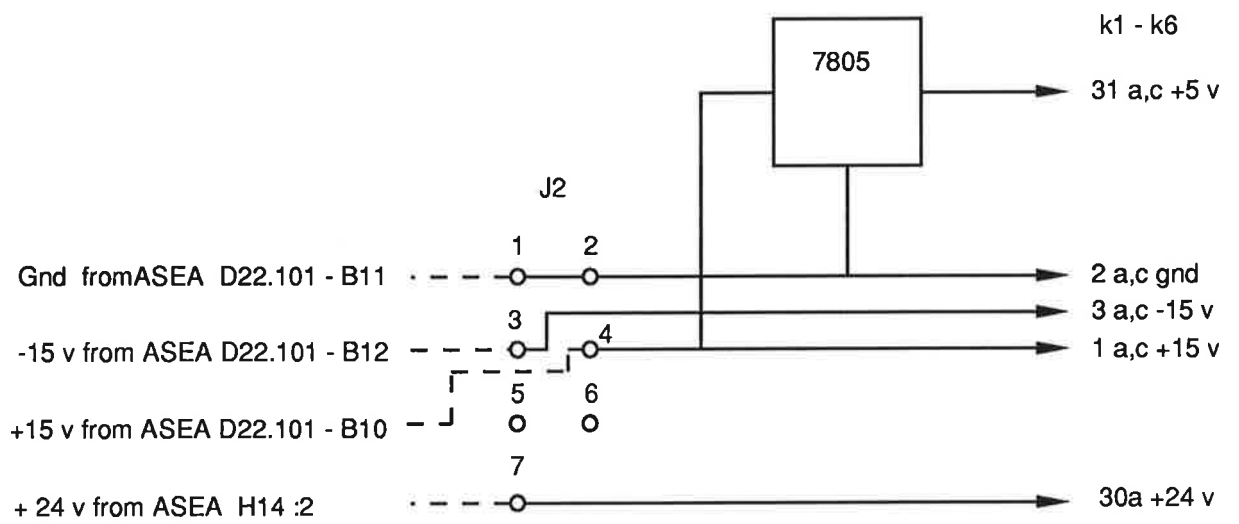


Back view



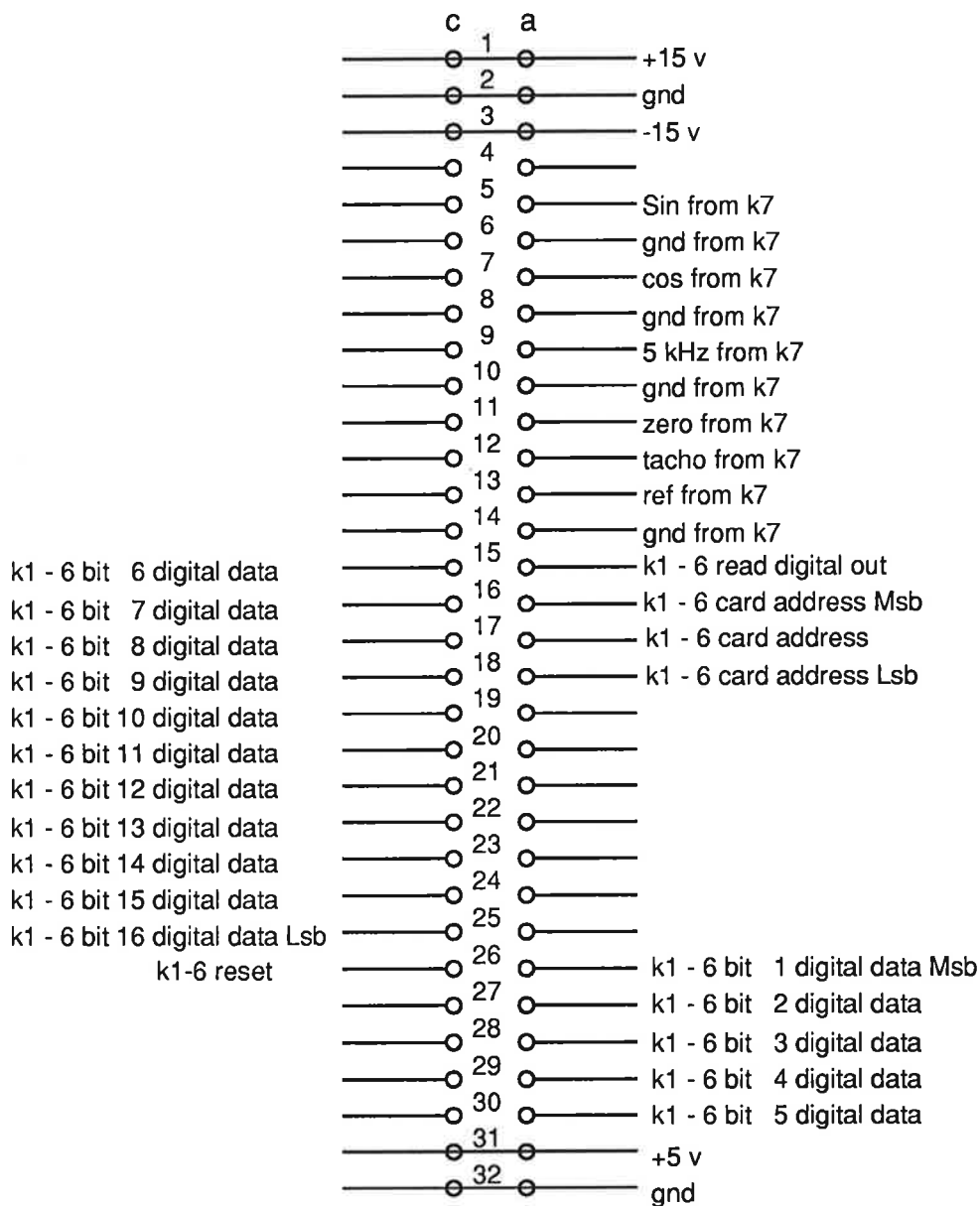
- k1 - k5 Resolver - Digital conv. module
- k6 Digital communication with computer
- k7 To Asea robot and interface
- J2 Power from ASEA Power drive unit

LTH Reglerteknik Lund	ASEA Robot LTH Unit 5 v power rack	Asea int.S 5 v Ps. J2
		900323 RB
		Rev. 900607 RB

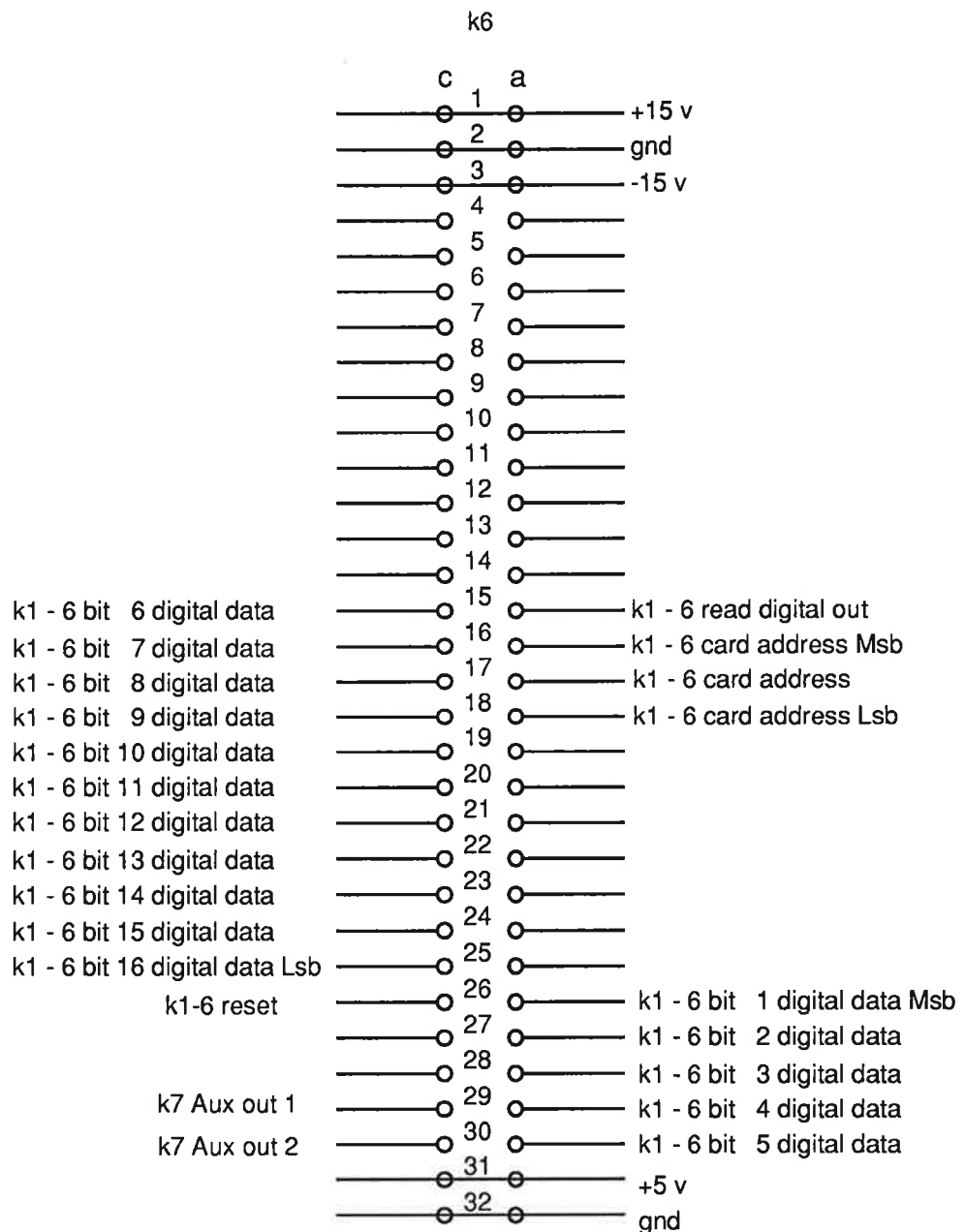


LTH Reglerteknik Lund	ASEA Robot LTH Unit Backplane	Asea int.S rack bpl.k1-k5
		900323 RB
		Rev. 900423 RB

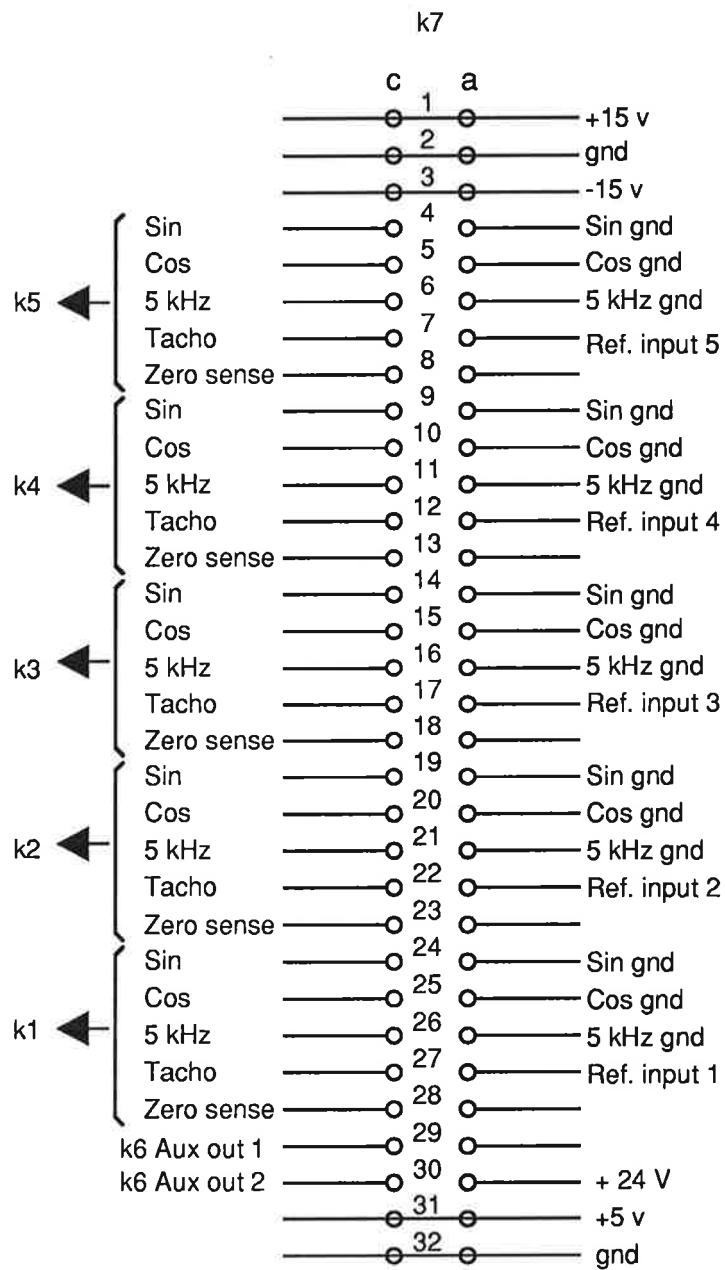
k1 - k5



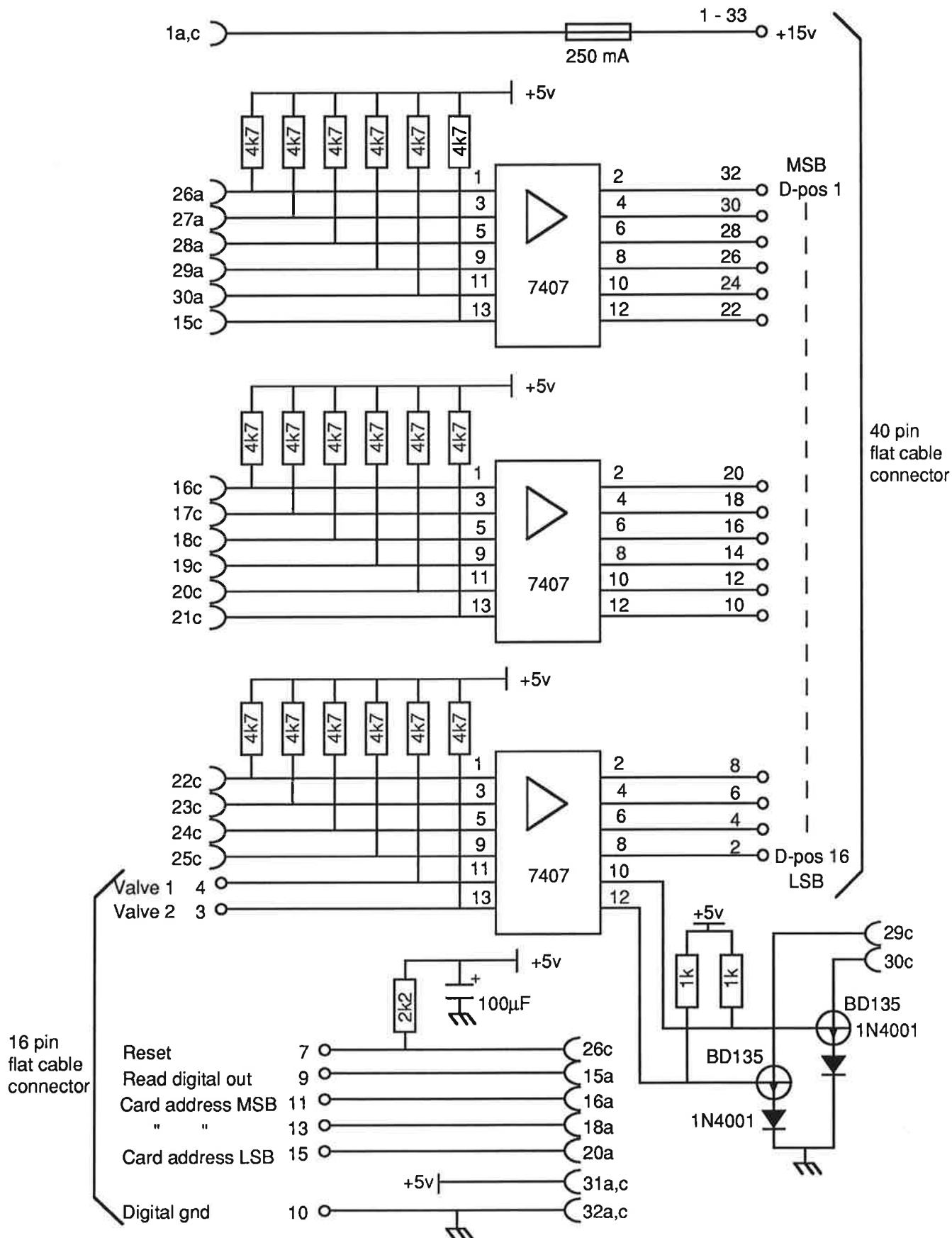
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		900423 RB



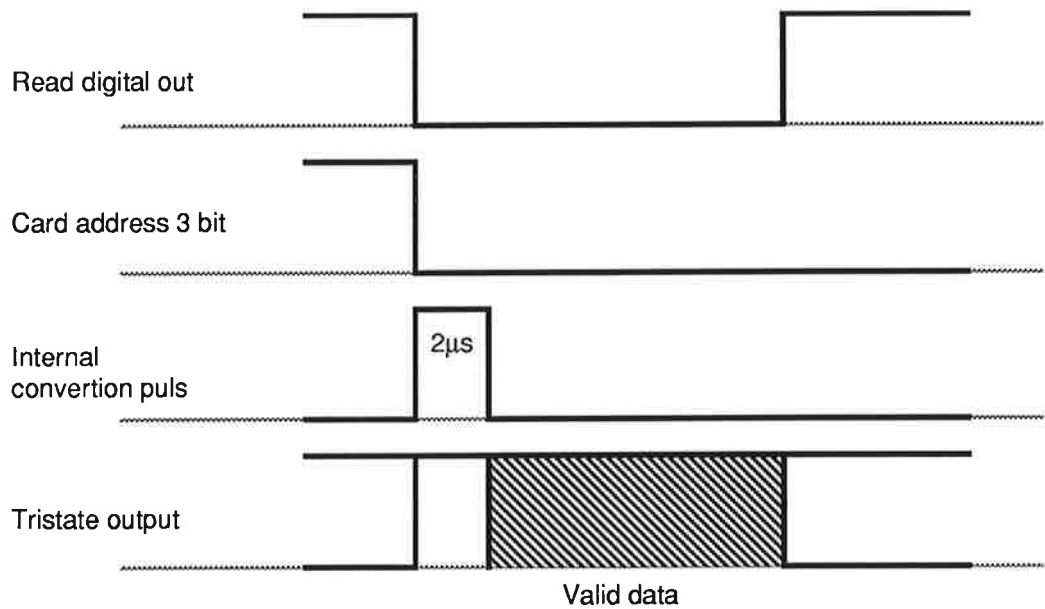
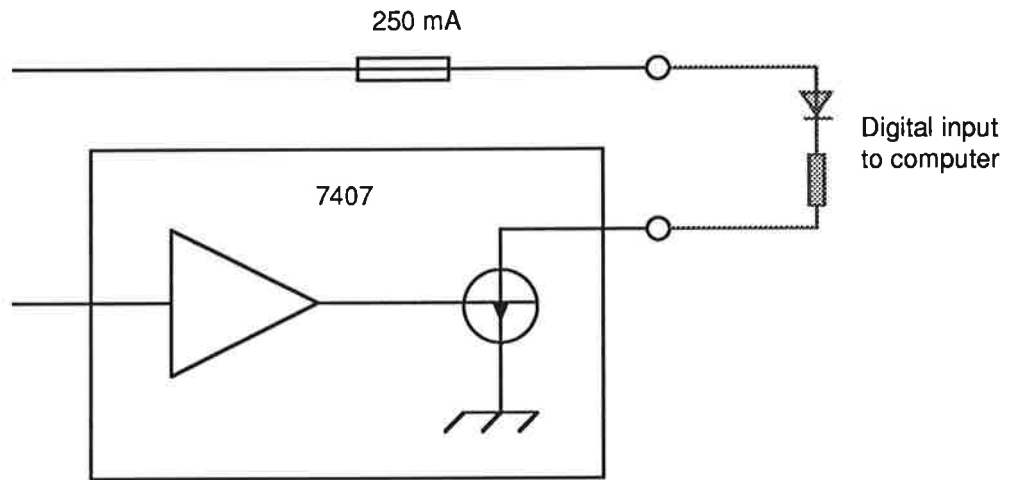
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		900323 RB

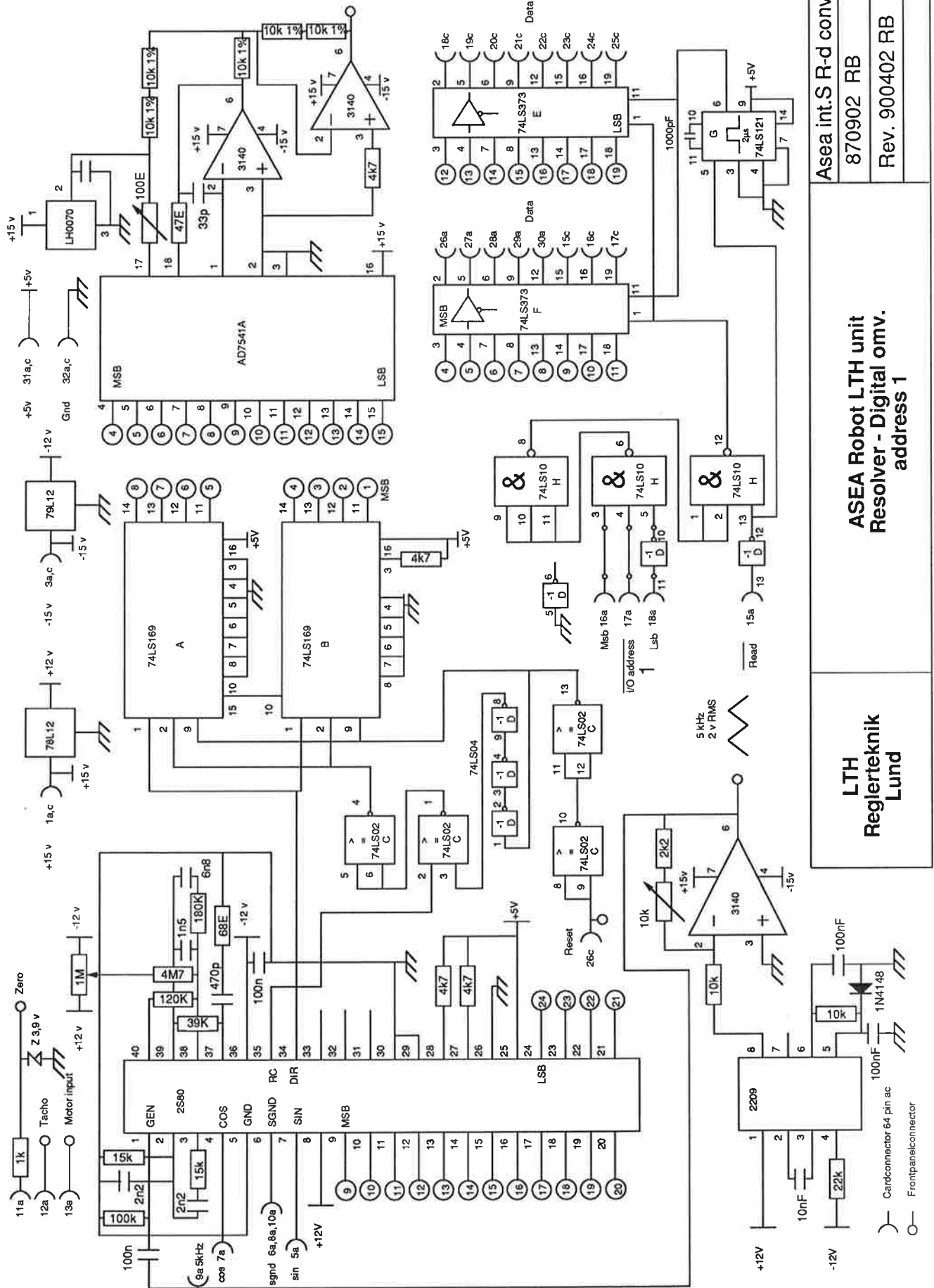


LTH Reglerteknik Lund	ASEA Robot LTH unit I/O module	Asea Int. I/O module
		900607 RB



<p>LTH Reglerteknik Lund</p>	<p>ASEA Robot LTH unit Digital positionsignal overview</p>	Asea Int. Dig I/O overview
		900521 RB





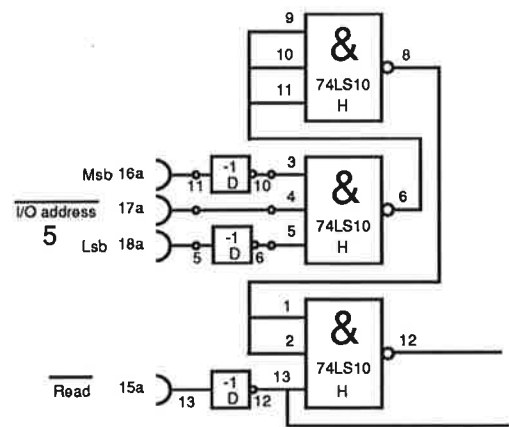
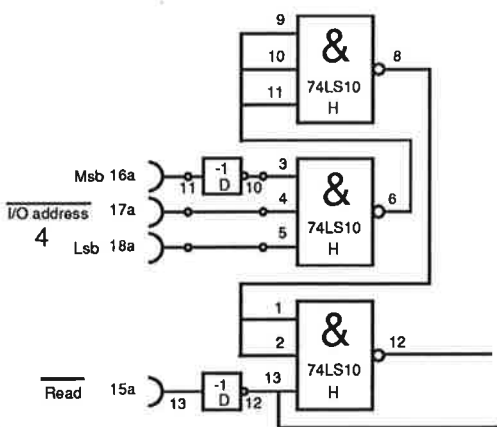
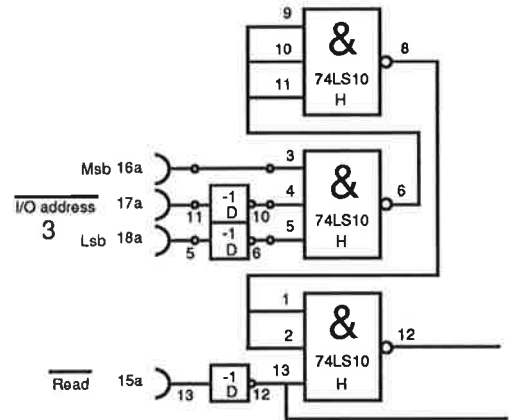
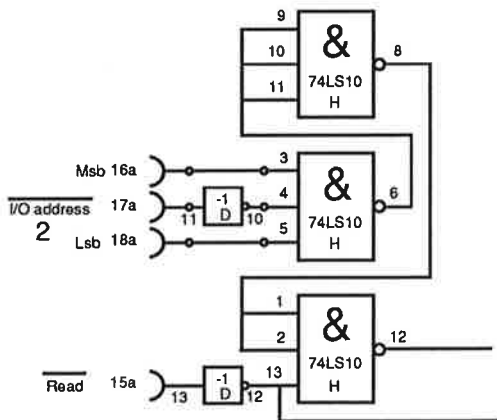
Asea int.S R-d conv
870902 RB
Rev. 900402 RB

ASEA Robot LTH unit
Resolver - Digital omv.
address 1

LTH
Reglerteknik
Lund

Cardconnector 64 pin ac
Frontpanelconnector

LTH Reglerteknik Lund	ASEA Robot LTH unit Resolver - Digital omv. address 2 - 5 mod.	Asea int.S R-d mod.
		900402 RB



1. Introduction

An industrial robot, like the ASEA IRB-6, is usually delivered with its control cabinet, control system, and operator's interface. These systems are cost optimized and normally forms a closed and rigid structure. Therefore, there are a number of design considerations if we are going to modify a system and to make it flexible and useful both for research and teaching. The objectives of such a modification could differ, but our goals are to do control experiments in a wide sense. The Robot Laboratory group within the Department of Automatic Control, Lund, Sweden, has its interests in control servos for robot control, and other aspects particular to robots such as path following, sensor integration, and robot programming. Aspects of mechanical design and design of power drive units are thus not major interests.

The first design decision, in modifying the robot system, is where to open up the system. With our interests as a background it is natural to keep the mechanics and the power drive units. The original control computer within the control cabinet is inaccessible for programming so it has to be left out. As a consequence, sensor interfaces originally being a part of the control computer has to be designed. However, the original system features a number of safety functions that are desirable to keep. These are e.g. emergency breaks that are essential for human protection, and there are also robot protections e.g. against overloading and current limitations.

The resulting system has been used for both research and teaching. As will be described in the following, the robot is now equipped with general interfaces so computer systems with standard AD and DA converters can be used. We have so far used both a system based on IBM PC/AT and a system based on a Sun Sparc work station plus a VME-based board computer for the direct computer control of our robot. The robot system with the modifications made, and with the door of the control cabinet removed, is shown below.

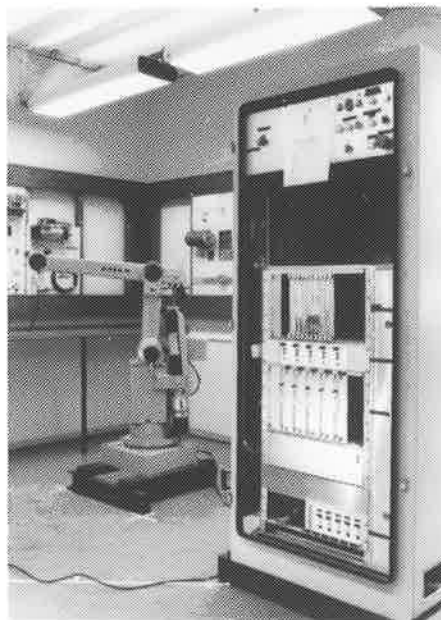


Figure 1.1 The modified robot system in our lab.

3. The modified control system

The modifications done to the robot system itself will now be described. The original robot was a standard ASEA IRB6 robot with the control system S2. The modifications related to the sensors are simple. They consist of cutting the wires and replacing the sensor system with our own. The situation concerning the drive units is a bit more complicated since it is desirable to keep major parts of the system. To keep the safety system we have to create an environment where the original control computer sees consistent measurements and control signals. This implies some strapping of signals and also that some of the cut wires have to be given certain values.

3.1 Wiring and cables

The resolver cables were disconnected at the robot base, i.e., at connectors X3, X4, and X5. Refer to ASEA manuals and to Appendix A for details (the names of signals, here and in the following, are the same as used by ASEA). New connectors, one for each joint, were then built on to the robot base, see Figure 3.1, and the resolver cables were connected. The tachometer signals and the zero position switch signals are still available in the original system, but also goes to the new connectors.

3.2 Control of power drive units

As described in Chapter 2, each motor drive unit can be used in three different modes: Internal velocity control of PI-type, Internal velocity control of P-type,

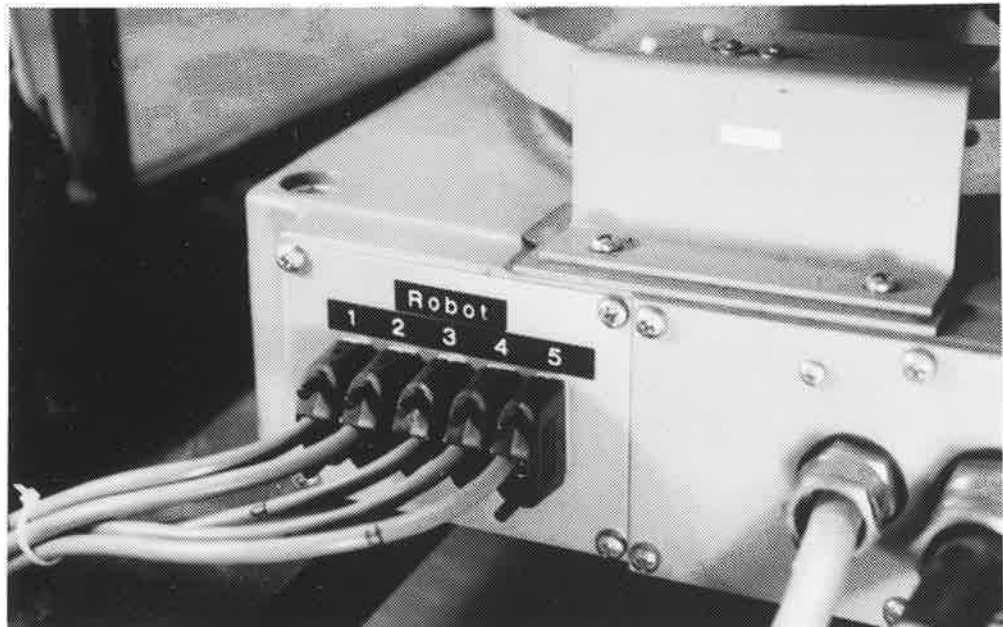


Figure 3.1 Connections to the five joints.

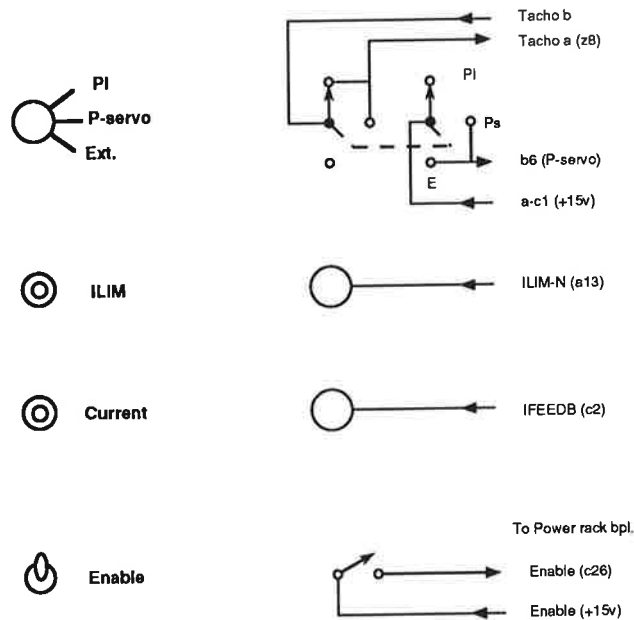


Figure 3.2 Front panel and signals connected.

and external velocity control. The mode is selected by the switches on the "LTH front panel", where also the signals "ILIM" and "Current" are made available, see Figure 2.3 for front view and Figure 3.2 for implementation. We have located each of these panels above the corresponding drive unit as shown in Figure 3.3.

The ILIM signal is a digital output going low when the drive unit for that joint has reached its current (i.e., torque) limit. A voltage proportional to the actual current (torque) is made available as the "Current" signal, which is useful for advanced position or path control when the analog speed control is used.

Each joint can also be disabled using the enable switch. The implementation shown in Figure 3.2 refers to ASEA's notion for the signals. Physically

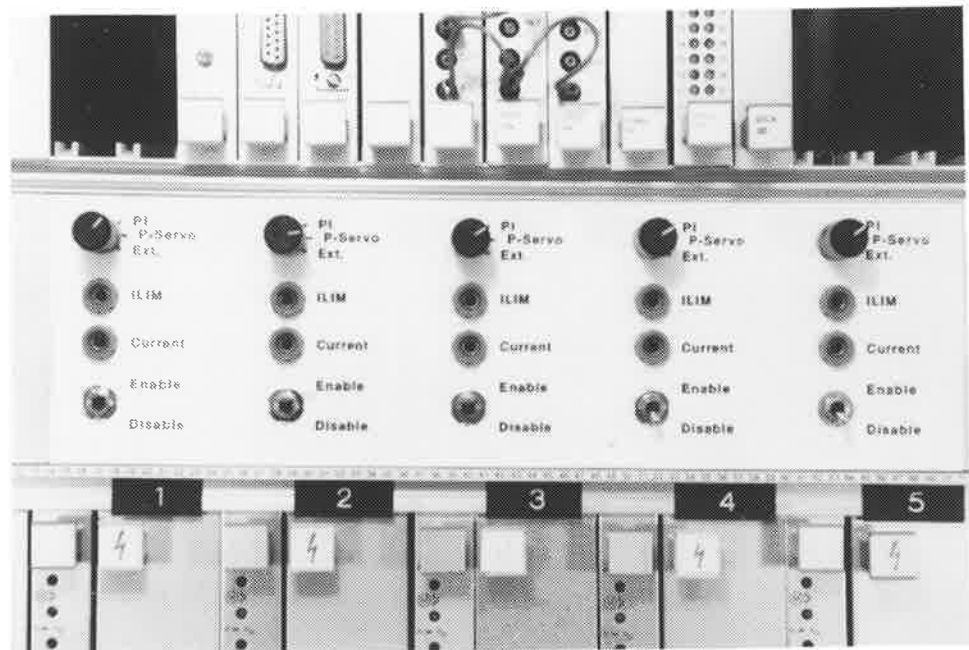


Figure 3.3 Location of front panels to the drive units.

the signals are reached on the backplane as shown in Figure 3.4. Refer to Appendix B for further details. Sensor signals are not effected by disabling the drive unit of the joint, only the motor is made powerless.

To use the P-servo (see Figure 3.2) mode, it is normally required that the ASEA-system is equipped with compliant control (also called soft-servo by ASEA). In our system we have the oldest version of the drive units, which have been modified according to Appendix C to be the same as the newer units with compliant control. It is possible that later versions of the drive units without compliant control requires even more changes. Instead, it is possible to buy the soft-servo option.

3.3 Fooling the original control computer

Because the resolver measurement have been modified, as described in Section 3.1 and Chapter 2, we have to supply new signals to the ASEA controller. By using the sinus feed for the resolvers as the signal coming from the resolver, the control computer gets consistent measurement for position $\equiv 0$. This is done by plugging some cables into connections available for fault-finding according to:

- Connect the 0V of board DSQC 103 to 0V on the DSQC 104 boards.
- Connect the SIN-signal of board DSQC 103 to FB1, FB2, and FB3 on the DSQC 104 boards.

Figure 3.5 is a picture of the connections.

Some modifications of the connections to the drive units are also required. The velocity references from the original control computer have to be cut because we use our own reference input (IN in figure 2.4). The torque limit indication (ILIM, see section 3.2) signals going from the drive units to the DSQC-boards have to be put to +15V. The latter change is to prevent jam-error detection (see next section). Details are shown in Appendix D.

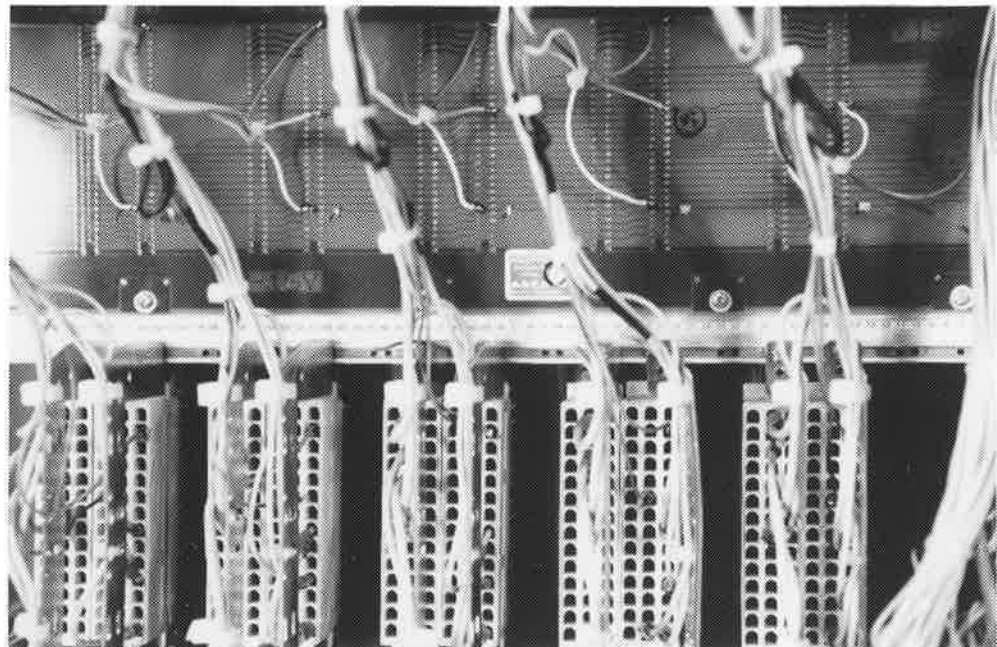


Figure 3.4 The backplane of the ASEA drive units where signals have been changed and added.

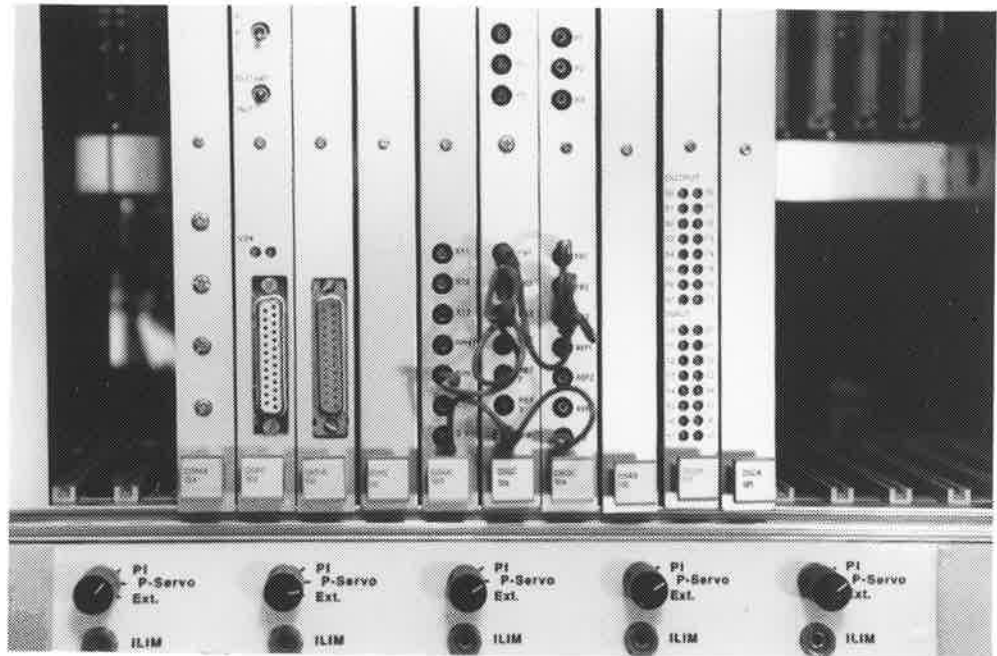


Figure 3.5 Original control computers and IO-boards, which are fooled by the extra cables in the middle of the picture.

3.4 Alarm and safety system

The emergency stop buttons and loops in the system still work. This means that all possible equipment for personnel safety (gates, light-beams) can be used as usually. The thermal overload detection for the motors also functions. The (in software) built in jam-error detection is, however, by-passed, but can be implemented as a detection of (almost) zero velocity with max torque (see ILIM above) for 0.2 seconds.

3.5 Teach pendant

After the modifications made, only the emergency stop of the teach pendant (or programming unit) can be used. Trying to move or program the robot with the original system will result in error messages.

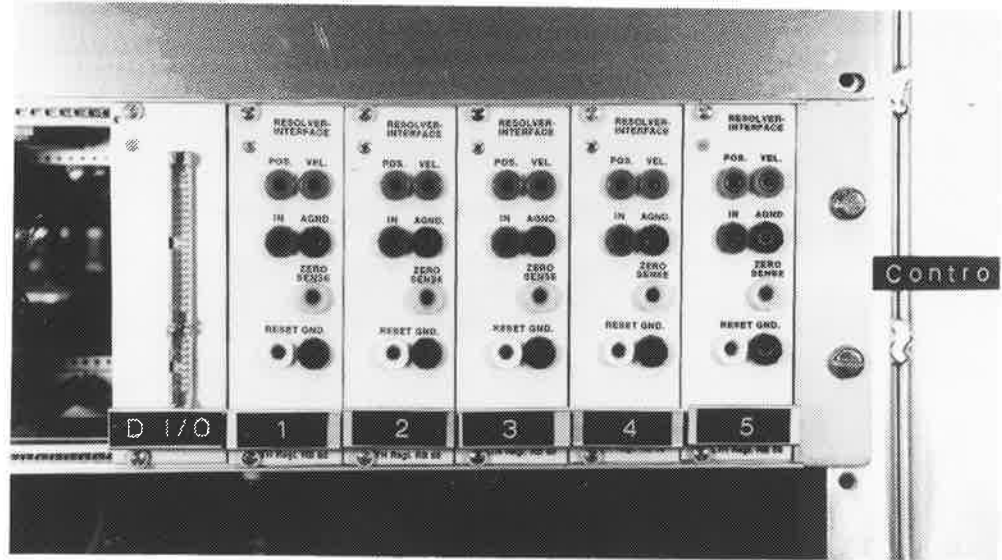


Figure E.1 Front view of the sensor interface rack.

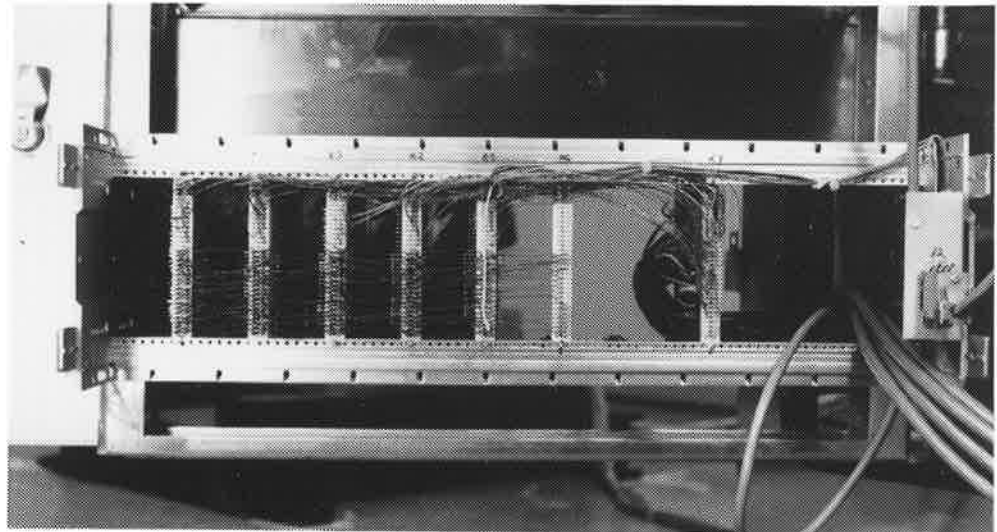


Figure E.2 Back view of the sensor interface rack.

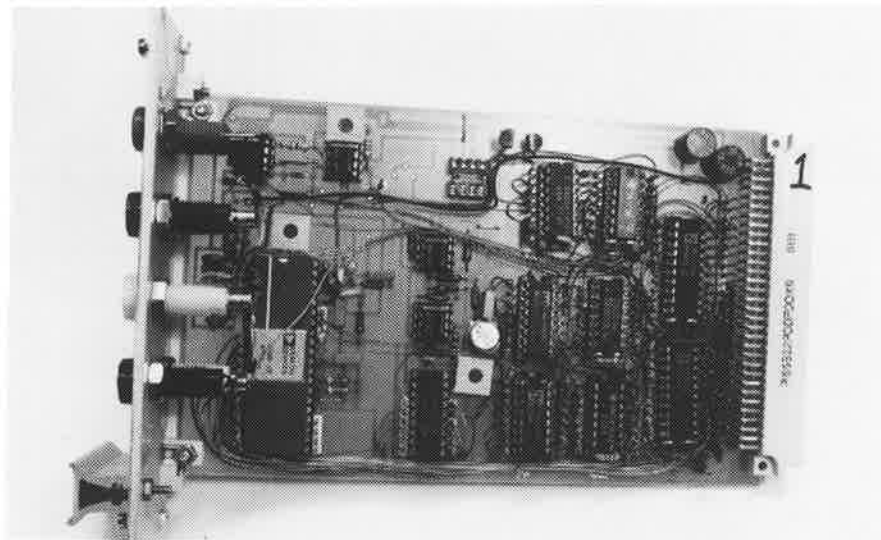


Figure E.3 Side view of one interface module (LTH module).