COMPONENT PLACEMENT ROBOT WITH WIRELESS ENERGY AND DATA TRANSFER

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INTRODUCTION
This paper presents the results of a two years research project Wireless Interconnected Robot (WICOR). This project has been subsidized by the Dutch government and is conducted by a consortium of partners; Philips Applied Technologies, Assembleon, IMEC-NL, FMTC, NTS and Eindhoven University of Technology.

The pick and place machine AX-501 of Assembleon is shown in Figure 1. This machine is composed of up to twenty independently operating robots whose tasks is to place components on printed circuit boards, [1].


In the existing system, the existence of moving cables introduces reliability problems with regard to achieving higher acceleration rates and speeds. As schematically shown in Figure 2, linear motor based robots drawing wireless energy and data transfer is aimed at eliminating this hard wiring limitation. In this unit each robot is responsible for a 4-DOF movement. The X- and Y-movements are supplied by linear motors and a small φ-Z actuator on the head (Figure 2) that makes the movement in Z direction and a rotation around Z-axis. An image camera is connected to the head.

FIGURE 2. WICOR manipulator.

CONTROL ARCHITECTURE
Lower bandwidths, higher transmission delays and higher rates of packet losses all of which are typical to wireless networks are addresses by an Ethernet network topology. The real time requirement is imposed on several processes, such as motion synchronization, minimum latency in pneumatic valve control and by machine safety. This topology also dictates that the control hardware and software implementing servo control loops is located on the moving parts of the robot, [1]. The control architecture is shown in Figure 3.

WIRELESS DATA TRANSFER
The implementation of the machine control bus follows a hybrid approach that combines optical and radio frequency (RF) links. Image data is transferred via optical free-air interconnection. The light is collimated into a beam size of approximately 3 mm with a free air distance of 2 m. In order to connect the two translating axes, prisms are used as shown in Figure 4.
The distributed control architecture with hard real-time requirements makes the latency of the radio communication (RF) very critical, i.e., maximum of 1 ms. A comparative study of possible RF techniques (Bluetooth, Zigbee, Wi-Fi, WiMedia) showed that real time requirements can only be met by WiMedia, [2]. It has high data rate and a low latency. This standard is based on the ultra-wide band radio technology. During the project, there was no fully compliant WiMedia hardware available, thus a platform based on a Wisair radio chip is incorporated by IMEC-NL and FMTC [2]. The developed platform as shown in Figure 5 also includes a 32-bit ARM microcontroller, and different interfaces (Ethernet, USN, serial, etc) providing wide range of connectivity possibilities.

**FIGURE 2.** WICOR control architecture with distributed motion control and with wireless connections.

**FIGURE 4.** Optical free-air interconnection.

**FIGURE 5.** WiMedia based RF-link.

**WIRELESS ENERGY TRANSFER**

The two moving axes are energized by wireless energy transfer, [3]. The system is composed of a power converter, two magnetic couplers, and two power conditioners as shown in Figure 6. The details of the magnetic coupler are shown in Figure 7. The power conditioners energize the servo drive as well as the control circuitry. Due to the strict thermal specifications, extra attention is paid to limit the dissipation in the moving parts. One of the important properties studied during the project is the back delivery of the energy to the power boards during deceleration.
The wireless power transfer system is shown in Figure 8 in detail. The input of the stationary power board is the 50/60 Hz mains. The output of this board generates a high-frequency (HF) AC voltage, which drives the y-coupler. Via the Y-coupler, this HF AC-voltage is contactlessly transferred to the Y-plateau. On the Y-plateau the voltage is rectified and conditioned in order to supply the controller and the motor amplifiers. Also on the Y-plateau this voltage is transferred to the X-coupler. Via the X-coupler this voltage is again contactless transferred to the X-plateau. Due to safety requirements, standby mode of the electronics is required. Thus, the system has two modes of operation, one is standby, the other mode is full-power. In the full-power mode, the HF AC-voltage generated by the stationary power board peaks to the maximum amplitude. In case of standby this amplitude is halved.
During the standby mode the X and Y motors cannot be driven properly, only the control circuits on the X and Y-platform will be active. The various circuits have a status output, which are set when a certain amplitude or voltage is present.

The stationary power board incorporates mains filtering, inrush relay, pre-conditioner and the chopper. The mains filter not only prevents disturbances on the mains to enter into the supply circuitry but also prevents the disturbances generated by the supply to enter into the mains. The inrush relay limits the inrush current when the supply is turned on. This way the circuits and capacitor banks in the supply are protected against high peak currents. With a control signal the supply can be turned off or on.

The pre-conditioner rectifies the low-frequency (LF) mains voltage and generates a constant 400 V DC voltage. The mains voltage can vary between 95 V and 265 V AC, the pre-conditioner converts this to a constant DC-voltage. The chopper consists of a half bridge which chops the 400 V DC voltage from the pre-conditioner at a frequency of around 100 kHz. This is done with an LLC-converter. Due to the resonant operation of the LLC-converter, the AC output current is close to a sine and will generate less high harmonics which could cause EMC-problems in the system.

CONCLUSIONS

The finalized WICOR demonstrator is shown in Figure 9. It is shown that the peak power of 600 W and a continuous power of 300 W can be transferred to the moving stages without forced cooling with an overall efficiency of 80% during normal operation, excluding the power gain of the back delivered energy.

The tests conducted on WICOR demonstrator showed that the application of wireless energy and data transfer in component placement robots is feasible. Moreover, EMC tests showed no excessive radiation exceeding the legal limits. For the prospect of the industrialization of the prototype, a reduction of the total moving mass, simplification, optimized packaging and cost minimization is required.

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REFERENCES

