

Adaptive Exercise Machine Control for Persons with Disabilities

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Presented at the RERC State of the Science Conference, Denver, CO,
USA, May 30-May 31, 2006.

ABSTRACT:

We make the recreation and exercise equipment accessible to disabled people by design changes to the equipment. Typical group of disabled people are the people on wheel-chairs and stroke patients.

Better user interfaces, mechanical design, motor control and virtual reality environments are part of this design changes. Finer adjustable motor control in terms of motion range, speed and force is needed to enable the people with very limited physical capabilities. Machines can auto configure themselves for disabled people in a customized way that is specific to that disabled person's abilities. In addition to making machines usable by disabled persons, we also want to make it attractive and motivate the disabled people to use the exercise machines. Example technologies to be used are: 1) virtual reality to create interesting environment, 2) finer adjustable motion control and auto-configuration capability to reduce the setup time and eliminate potential frustrations, 3) collect and track data on progress of each individual, and auto-adjust exercise program according to progress.

From financial point of view, insurance companies are more likely to pay for these machines if it can be demonstrated that it makes a measurable improvement in the lives of the patients.

INTRODUCTION

- Most exercise facility devices are not readily accessible to individuals with physical, sensory or cognitive impairment.
- Some facilities have devices accessible to people with certain physical disabilities, however, these devices do not provide satisfaction comparable with that available to people without disabilities.
- Currently available equipment lacks capability to provide fine adjustments for force and speed low enough for many disabled people can use.
- Machines require users to configure as well as remember settings.
- Access to machines essentially requires expert supervision throughout exercise program which may discourage participation and adherence .
- Very few keeps track of the progress of each individual in the exercise program

OBJECTIVES

New Capabilities

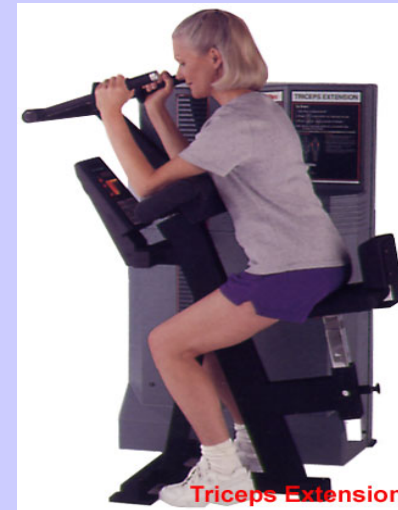
- Develop technologies for exercise machines to identify the user and automatically adapt to needs and capabilities (wireless technologies).
- Finer computer controlled motion: force (resistance), speed, range.
- Automatically keep track of each individual's progress (record data).

Pilot Demonstrations:

- Modify appropriate commercial fitness and exercise machines to incorporate this adaptive exercise control capability for use by people with different strength levels.
- Evaluate feasibility, efficacy and safety of adaptive machine control to increase access to and participation in regular exercise for persons with disabilities.

Current State of Art

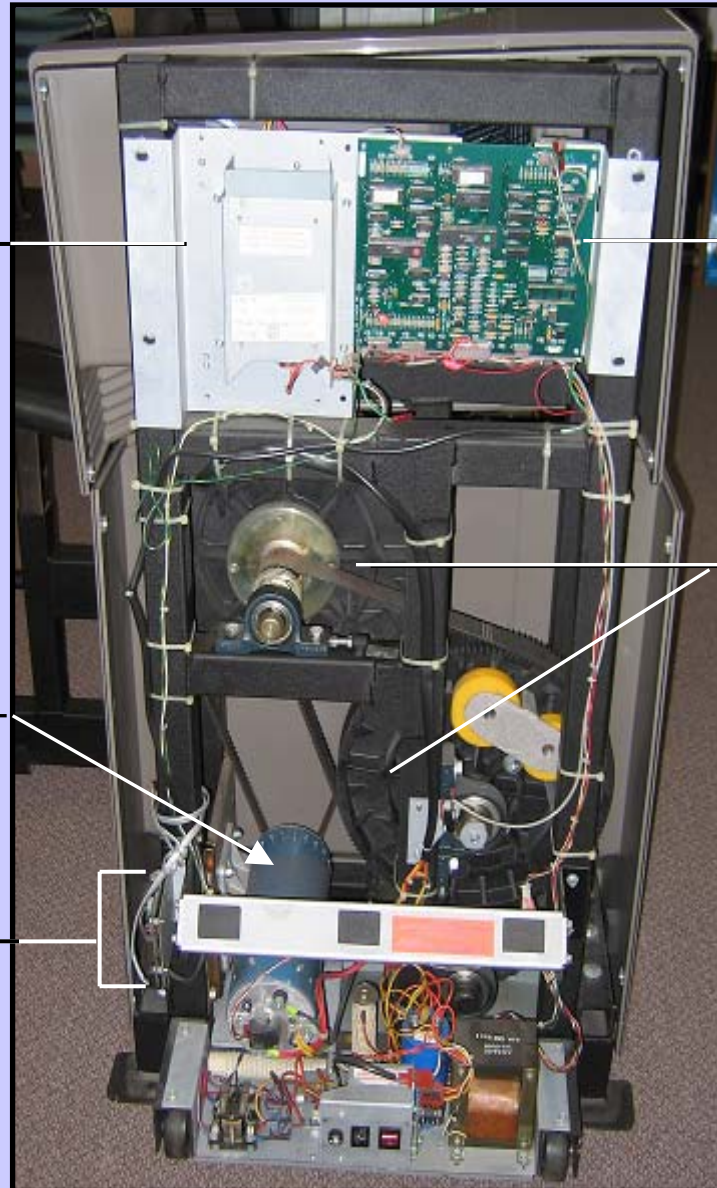
- “LifeCircuit” line of strength training machines (by Life Fitness Inc) used to demonstrate the concept of automatic configuration.
- “LifeCircuit machines” have identical mechanical and electrical components with differences in control software and shape of lever arms.
- Motion of machine is governed by single degree of freedom i.e. rotation of level arm.



Lifecircuit strength training machine: electromechanical



Driver



Input and Output Interface Module

Motor



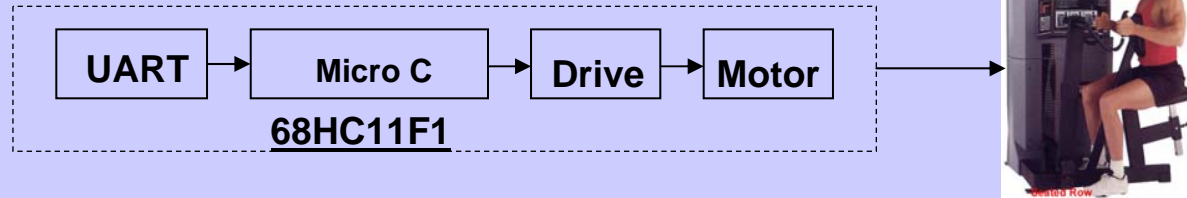
Microcontroller

Gear Mechanism



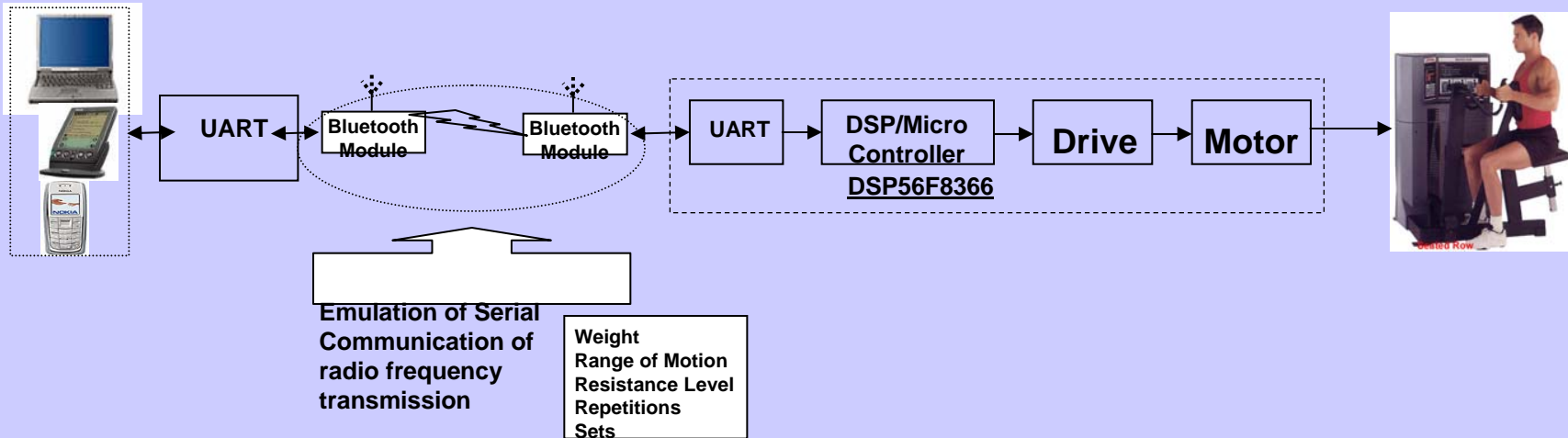
Display Panel

Current and Proposed Controls



Current Control System of Seated Row Lifecircuit™ Machine by LifeFitness

Personal Data Assistants



Proposed Model of Control System of Seated Row Lifecircuit™ Machine by LifeFitness

Motor and Drive Circuit

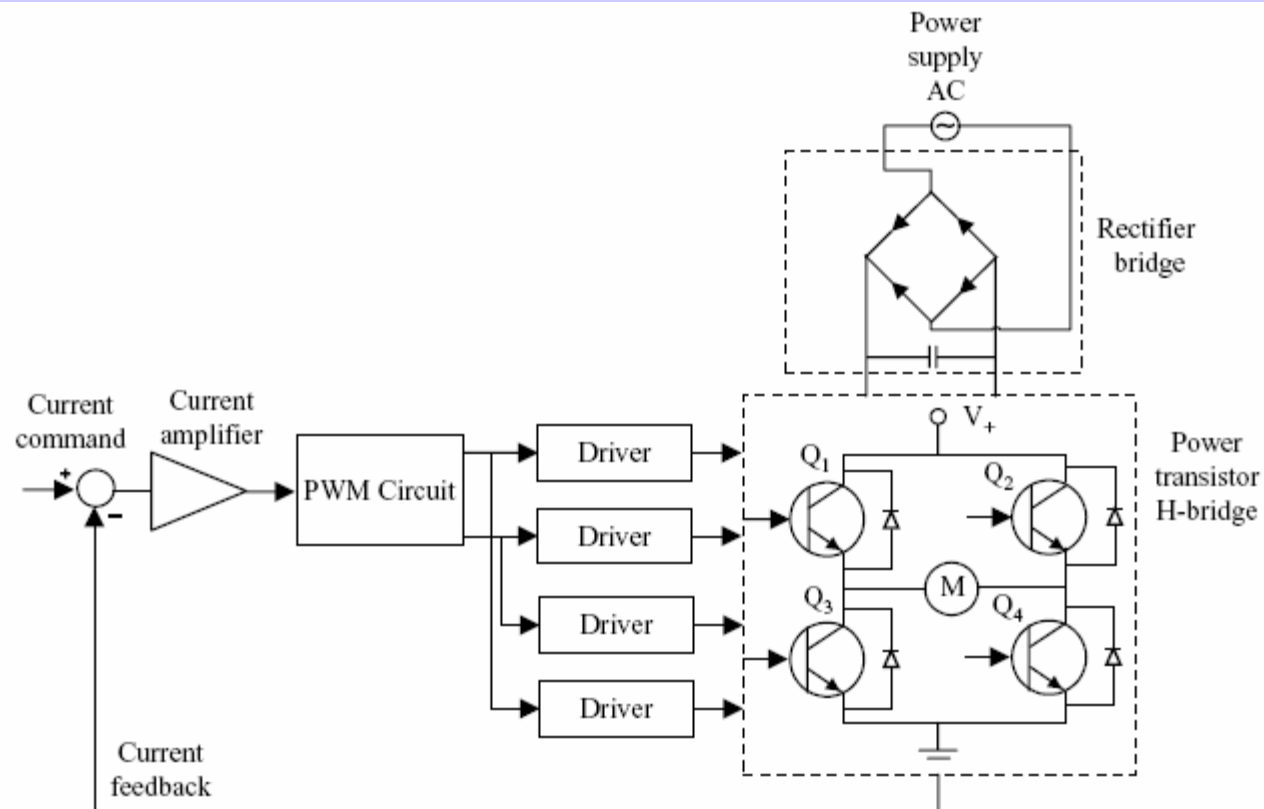


FIGURE 8.31: Block diagram of the brush type DC motor drive: PWM amplifier with current feedback control.

Closed loop motor control

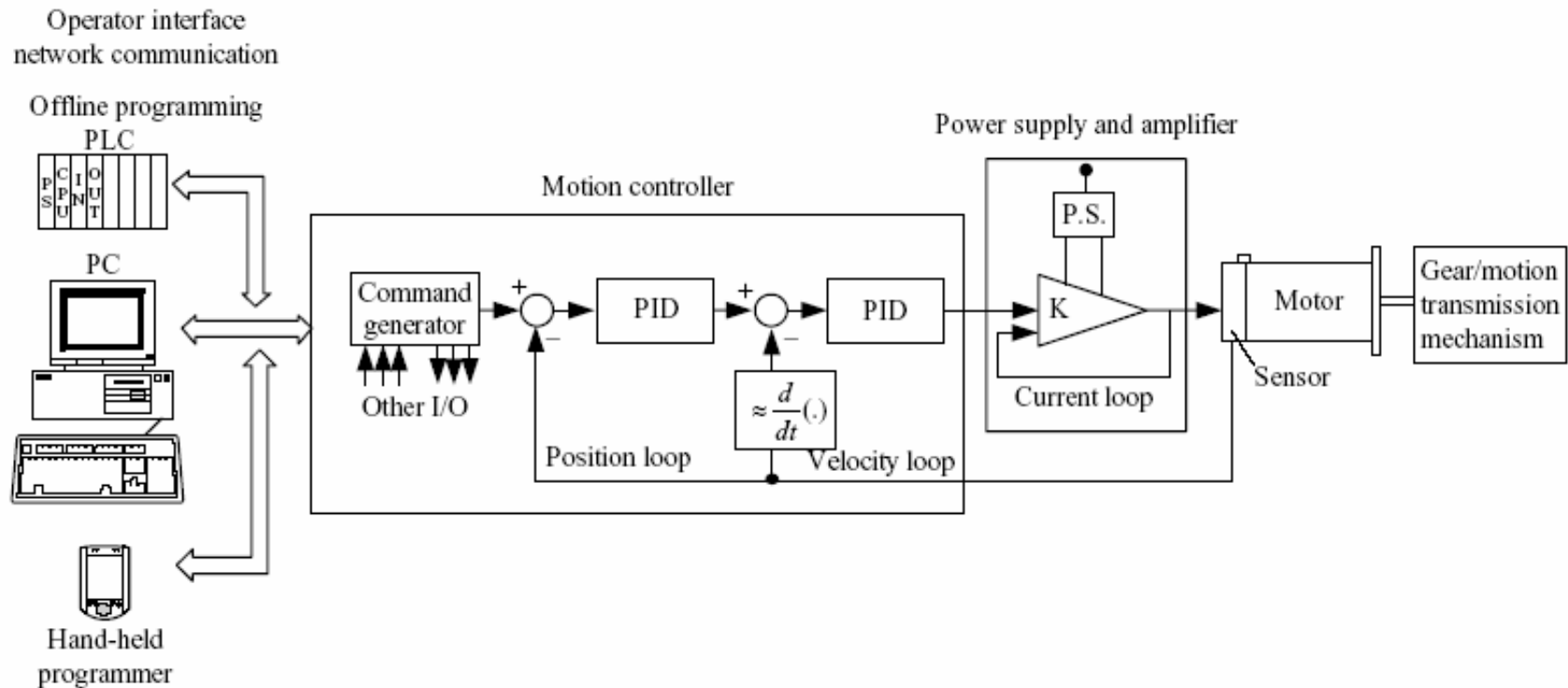


FIGURE 10.4: Components of a single-axis servo-controlled motion axis: motor, position sensor, power supply and amplifier (drive), motion controller for servo loop, machine level controllers (PLCs), and operator interface devices.

Closed loop position/speed control algorithms: PID

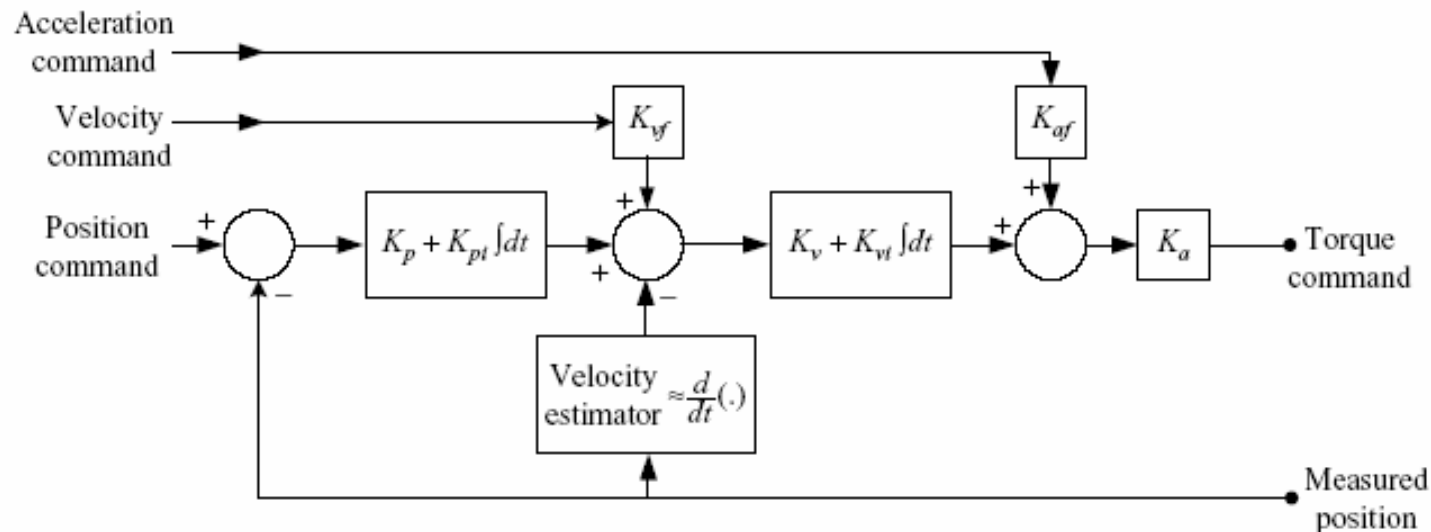
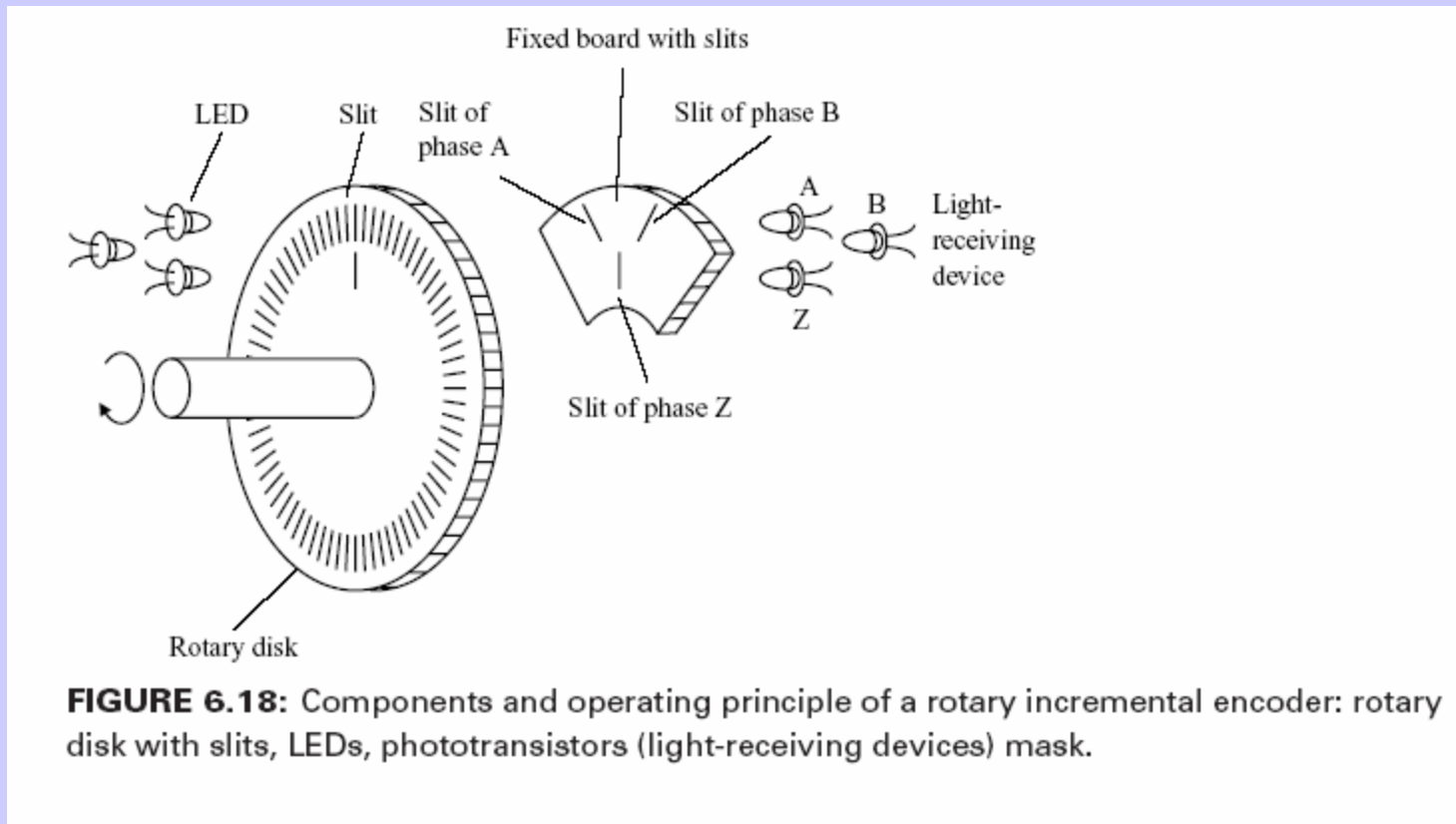


FIGURE 10.5: An example PID control algorithm implemented by a commercially available motion controller. Notice that practical PID control algorithms for servo motion control includes feedforward terms in addition to the textbook standard PID gains. Other modifications may include the addition of deadband, limits on integral control, activation and deactivation logic for integral action, integrator anti-windup, friction, and backlash compensation logic.

Position and Velocity Measurement



$$V = \Delta X / T_{\text{sampling}}$$

$$V = 1[\text{count}] / T_{\text{period}}$$

Primary features Lifecircuit machines provide wide design latitude:

- ◆ Flexibility to integrate wireless communication for configuration and monitoring.
- ◆ Adjustability of the resistance load and concentric/eccentric loading.
- ◆ Identification and modification the range of motion of user.
- ◆ Assignment of the number of repetitions and sets.
- ◆ Adjustability of the seat.
- ◆ Allowance for multiple information input/output formats.

PROGRESS

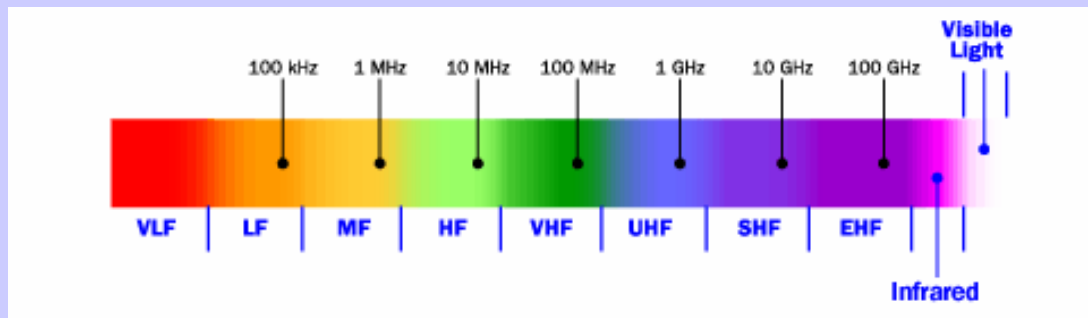
- Upgraded Lifecircuit machines' microcontroller with Motorola 16 bit DSP (DSP56F8366).
- Other components motor, encoder, amplifier, gear mechanism would not need any change.
- **The new DSP provide capabilities to**
 - **Incorporate finer adjustments of machine parameters,**
 - **Storage of user data, record the user work out information**
 - **Integrate Bluetooth module for wireless communication**
- Completed the design and building a prototype of motion controller board.
- Procured development tools, Code Warrior IDE for software development to efficiently provide user defined functionalities.
- Attained good knowledge of hardware and software interfacing

- Currently working on microcontroller software to efficiently control speed, velocity calculation, direction of motion, and load resistance for very low and intermediate ranges of adjustments.
- Rehabilitation Engineering Advisory Panel (REAP) suggested for use of Personal Data Assistants (PDA) like Bluetooth enabled Laptop, PDA's, Cell phones and custom made wrist bands.
- PDA will enable
 - Secure storage of personal data and exercise activity,
 - Allowing health care providers to track progress, improvements and potential problems.
- Determined hardware module to integrate Bluetooth wireless technology.

Bluetooth Basics

Bluetooth, wireless communication technology between multiple digital devices, is essentially a networking standard that works at two levels:

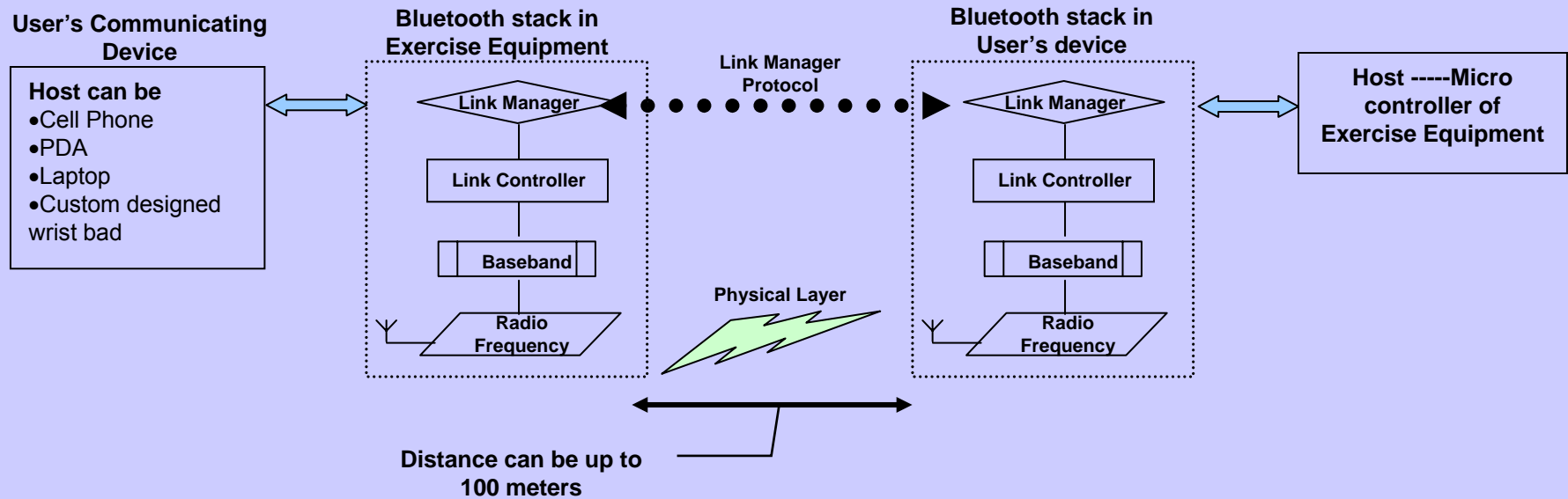
1. It provides agreement at the **physical** level –
Bluetooth is a [radio-frequency](#) (2.402 GHz-2.48 GHz) standard- wireless. Within 10m radius space.



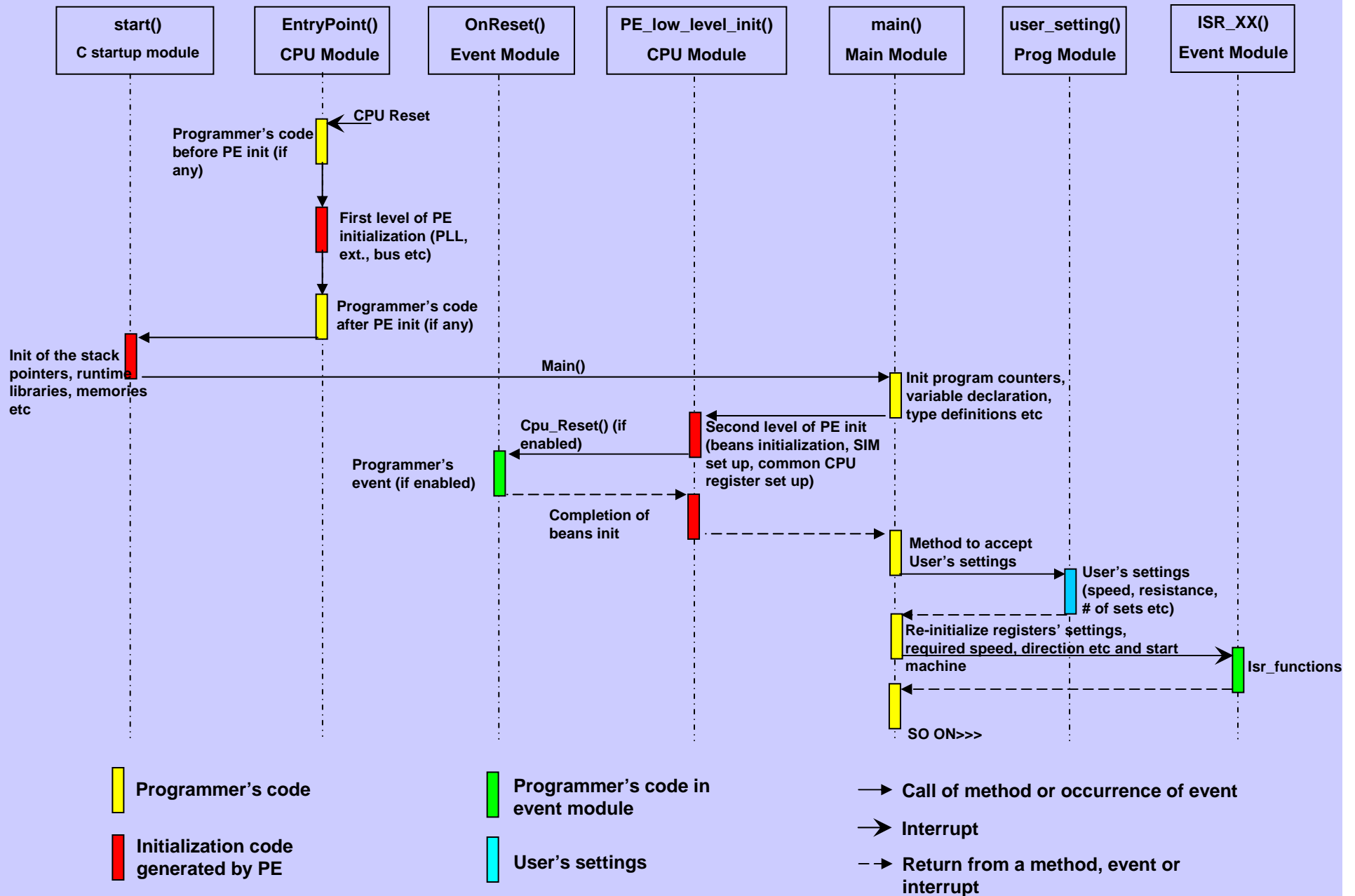
2. Protocol: communication data format (stuffing the bits), when to send, how to interpret, how to make sure the data is not corrupted.



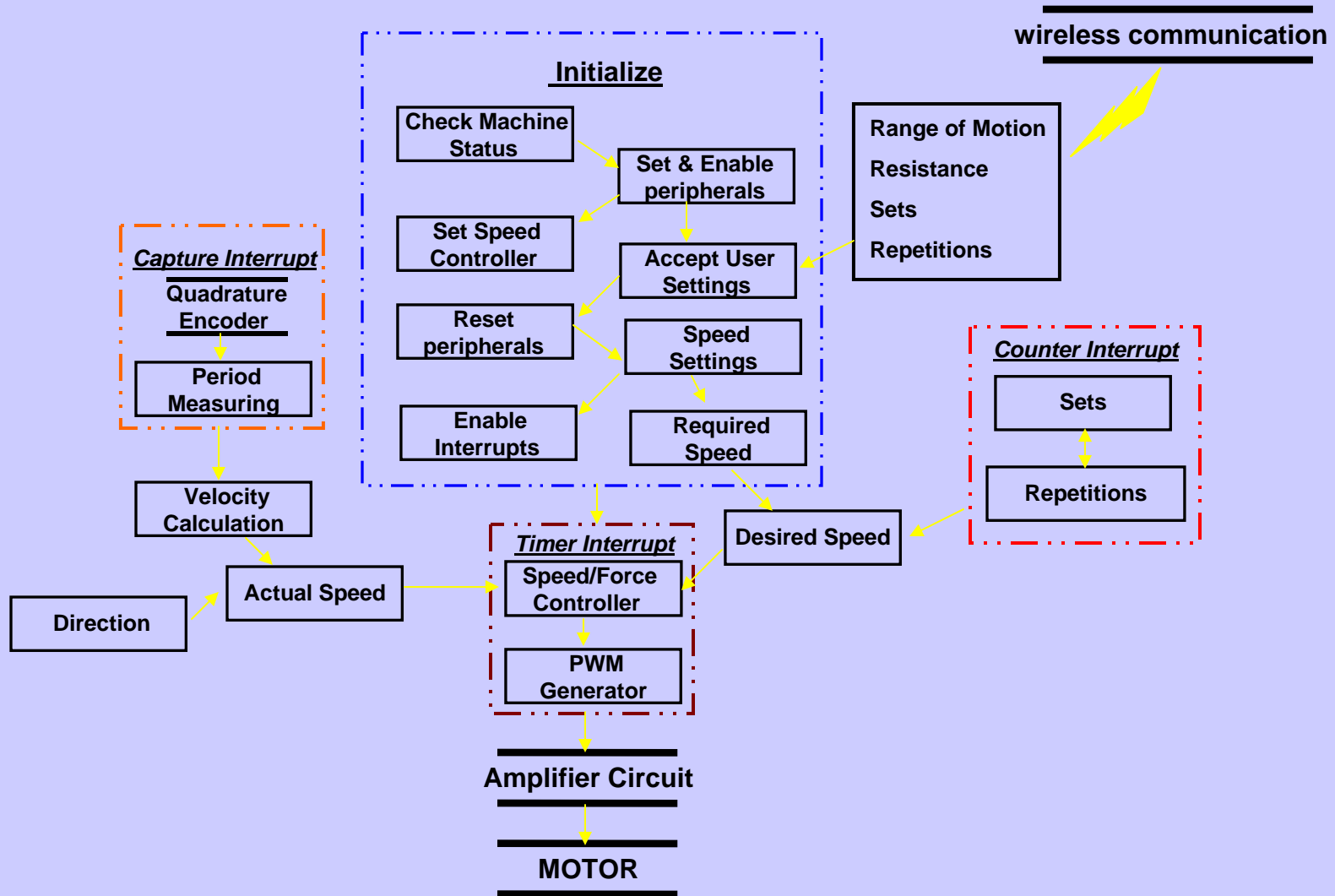
CONCEPT OF BLUETOOTH WIRELESS COMMUNICATION



EMBEDDED PROGRAM FLOW



DATA FLOW



SUMMARY and FUTURE GOALS

- Complete prototype with new microcontroller allowing for low resistance training.
- Complete integration of Bluetooth technology.
- Conduct initial subject testing with adapted machine.

THANK YOU

ANY QUESTIONS ?