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# Remote Controlled Solar Ploughing Machine

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***Abstract*: India's agricultural sector, which supports the livelihood of about 54% of the population, still relies heavily on traditional and diesel-powered equipment for field operations such as ploughing. This paper presents the design and development of a low-cost, remote-controlled, solar-powered ploughing machine intended for small and marginal farmers. The system uses wireless RF communication to remotely operate the machine from a distance, an Arduino Nano (ATmega328P) microcontroller to regulate the speed of the ploughing DC motor, and a solar panel with a charge controller to recharge the onboard rechargeable battery. By eliminating diesel consumption and manual draft labour, the proposed machine reduces cultivation cost, avoids exhaust emissions, and is simple enough to be operated without specialized training. A working prototype was built and tested, confirming remote operability over short range and functional ploughing action driven entirely by solar-charged battery power.**

***Keywords*: Wireless RF Communication, Solar Ploughing Machine, DC Motor, Arduino Nano, Remote Control, Renewable Energy Agriculture.**

## 1. Introduction

Agriculture remains one of the major economic sectors in India, employing close to 54% of the country's workforce, yet productivity is still constrained by a mix of traditional and modern farming practices. In several regions, cattle-drawn ploughs remain in use, and such traditional farms exhibit some of the lowest per-capita productivity and farmer incomes. Since 2002 India has become the world's largest manufacturer as well as the largest market for tractors, accounting for roughly 29% of global tractor output as of 2013, yet tractor ploughing remains costly for small landholders once rental, diesel, and labour wages are accounted for.

This project, the Remote-Control Solar Ploughing Machine, is designed to reduce environmental pollution from exhaust gases, make use of renewable solar energy, and lower the recurring cost of ploughing operations. The machine is operated using a wireless RF remote so that an operator can control ploughing action from a safe distance, encouraging even non-expert or younger users to participate in mechanized agriculture. The long-term goal of the project is to extend the platform so that additional tillage tools can be mounted on the same remote-controlled chassis.

Since the invention of the tractor in 1921, little further mechanization has been introduced specifically for the ploughing step itself. Existing ploughing methods largely remain fully manual operations carried out using tractors or draft animals such as cows and horses, both of which come with high recurring cost, physical strain, or dependence on fuel.

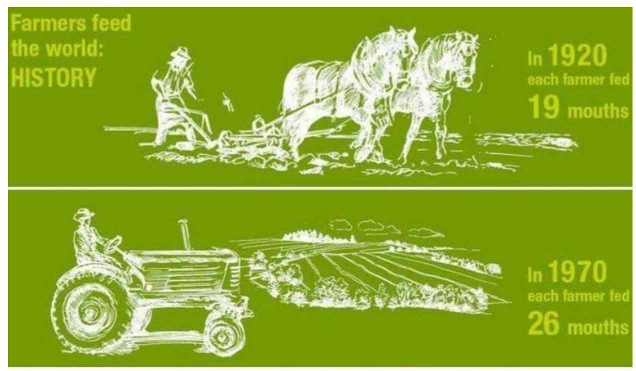

Fig. 1. Evolution of farm productivity: draft-animal ploughing (1920) versus tractor ploughing (1970)


Fig. 2. Assembled prototype of the remote-control solar ploughing machine

The proposed system replaces manual and diesel-based ploughing with a compact, battery-powered machine that is:

- Remote operated: controlled wirelessly over a distance of about 15 metres using a radio-frequency (RF) remote-control unit, removing the need for the operator to walk behind the machine.

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Compact and low-cost: ploughing one hectare of land by conventional tractor rental costs approximately ₹3,000 in diesel and labour wages; the proposed machine reduces this to only a nominal annual maintenance cost.
Solar powered: an onboard solar panel continuously recharges the system battery, removing dependence on grid electricity or diesel.

A working prototype of the assembled machine, showing the solar panel, battery/electronics enclosure, drive motors, and rotary ploughing discs, is shown in Fig. 2.

## 2. Literature Survey

Kronthaler (EURAC Research, Institute for Renewable Energy, Bolzano, Italy) presented a screening methodology to evaluate the economic feasibility and environmental impact of Vehicle-Integrated Photovoltaic (ViPV) systems using a range of indicators, providing a basis for assessing solar-integrated mobile platforms such as the one proposed in this work.

Selver Senturk (Turkish Agricultural Monitoring & Information Centre, Istanbul Technical University) investigated parcel-based Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) mapping techniques over full, unmasked satellite image frames to separate irrigated from unirrigated farmland yield shares, highlighting the broader push toward data-driven and technology-assisted agricultural practice that motivates mechanized, sensor-ready platforms of the kind developed here.

## 3. System Design and Methodology

The machine is built around five functional subsystems: a solar power-generation and charging subsystem, a rechargeable battery, an Arduino Nano control unit, an RF wireless remote-control link, and a DC motor drive train connected to the ploughing discs and wheels. Each subsystem is described in the following sections.

A solar panel is an assembly of photovoltaic (PV) modules that convert incident light energy into direct-current (DC) electricity through the photovoltaic effect. Individual modules are typically rated between 100 W and 320 W under standard test conditions (STC), and multiple modules or cells can be combined in series or parallel to obtain the desired voltage and current. Fig. 3 shows a representative solar panel array, and Fig. 4 illustrates the overall power flow from solar irradiance through the panel, charge controller, and battery to the load.

Fig. 3. A solar photovoltaic panel array

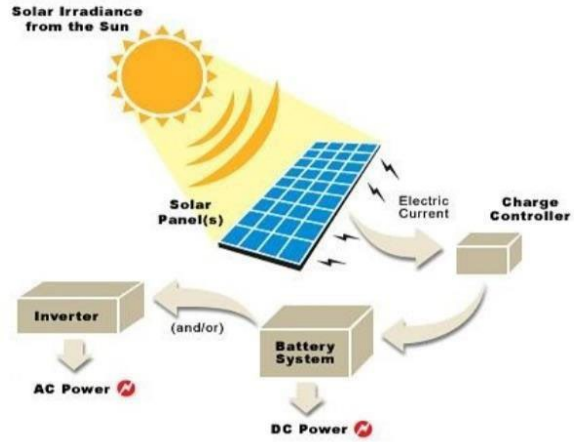


Fig. 4. Working principle of a solar power system: panel → charge controller → battery → load

A solar cell can be modelled as a current source (generating photocurrent Jsc) in parallel with a diode representing the dark current, together with a series resistance Rs and a parallel (shunt) resistance Rp that account for real, non-ideal conduction losses. For an ideal diode the dark current density is Jdark(V) = J0(e^(qV/kBT) − 1), so that the resulting output current density is J = Jsc − J0(e^(qV/kBT) − 1). Setting J = 0 in this expression gives the open-circuit voltage, Voc = (kBT/q)·ln(Jsc/J0 + 1). The maximum power point occurs between short circuit (V = 0) and open circuit (V = Voc), at a voltage Vm and current density Jm, giving maximum power density Pd,m = JmVm. The fill factor FF = JmVm/(JscVoc) expresses how effectively the open-circuit voltage and short-circuit current are utilized at the maximum-power point, and the overall efficiency of the cell can then be written as η = JscVocFF/Ps, where Ps is the incident light power density.

A solar regulator, or charge controller (Fig. 5), is placed between the panel and the battery to regulate the charging current and prevent the battery from being overcharged or deep-discharged; in this design it also allows the ploughing motor load to be driven directly while the battery continues to charge.

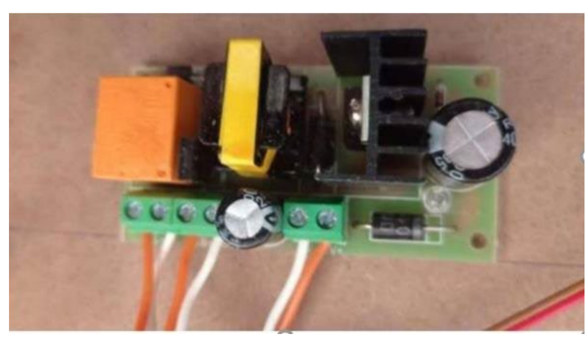

Fig. 5. Charge controller/solar regulator circuit board used to manage battery charging

Energy from the solar panel is stored in a 12 V rechargeable lead-acid battery (Fig. 6), composed of six 2 V cells connected in series. Each cell consists of a positive plate coated with lead-dioxide paste and a negative plate of sponge lead, separated by an insulating material. Unlike a single-use primary cell, this secondary (rechargeable) battery can be discharged and recharged repeatedly by an applied current, making it suitable for continuous solar recharging in the field.


Fig. 6. 12 V rechargeable battery used for onboard energy storage

The control intelligence of the machine is provided by an Arduino Nano board (Fig. 7), a compact, open-source microcontroller platform built around the ATmega328 (or ATmega328P) 8-bit AVR microcontroller. Key specifications are summarized in Table I, and the physical pin layout of the Nano board and the ATmega328P-PU pinout are shown in Fig. 8 and Fig. 9 respectively.

Fig. 7. Arduino Nano development board

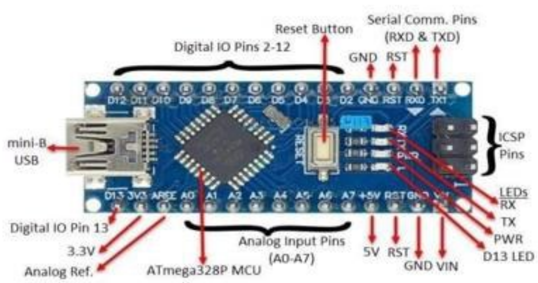


Fig. 8. Arduino Nano pin-out and functional block layout

Table 1
Arduino Nano specifications

| Parameter | Value |
|---|---|
| Microcontroller | ATmega328 |
| Operating Voltage | 5 V |
| Input Voltage (recommended) | 7 – 12 V |
| Input Voltage (limits) | 6 – 20 V |
| Digital I/O Pins | 14 (6 provide PWM output) |
| Analog Input Pins | 6 |
| DC Current per I/O Pin | 40 mA |
| Flash Memory | 32 KB (0.5 KB used by bootloader) |
| SRAM | 2 KB |
| EEPROM | 1 KB |
| Clock Speed | 16 MHz |

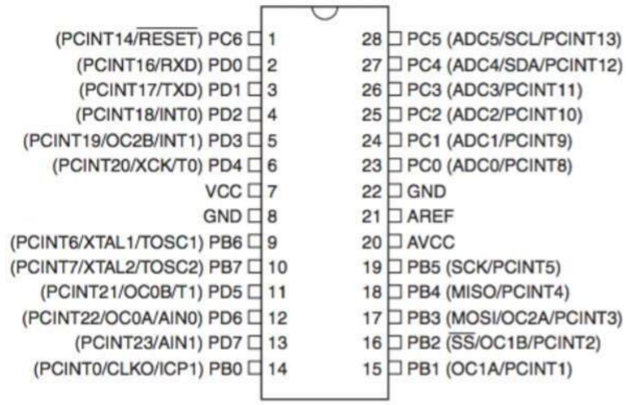


Fig. 9. Pin diagram of the ATmega328P-PU microcontroller used on the Arduino Nano

Remote operation is achieved using an nRF24L01 2.4 GHz transceiver module (Fig. 10) interfaced to the Arduino Nano over SPI. The module operates over the 2.4 GHz ISM band with a maximum air data rate of 2 Mb/s, and can communicate on 125 different channels, allowing up to 125 independently operating modems in the same location; each channel can support up to 6 simultaneously communicating units. Key technical specifications are listed in Table 2, and Fig. 11 illustrates how multiple nRF24L01 modules can address one another over distinct channels.


Fig. 10. nRF24L01 2.4 GHz wireless transceiver module

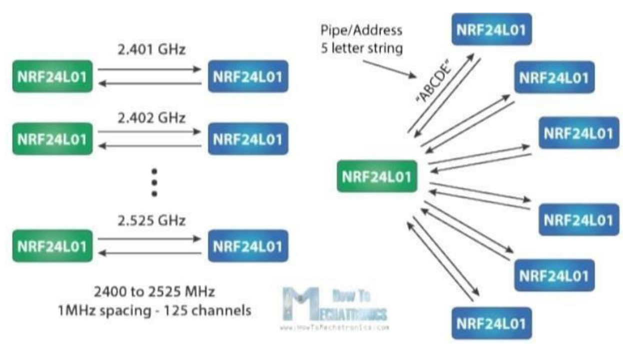


Fig. 11. Channel and address allocation across multiple nRF24L01 transceiver pairs

Because three of the eight module pins (SCK, MOSI, MISO) are dedicated to SPI communication, they must be wired to the corresponding SPI pins of the Arduino, while the CSN and CE pins connected to any digital I/O pin - set the module into standby, active, transmit, or command mode. A representative transmitter/receiver wiring arrangement between two Arduino Nano boards and their nRF24L01 modules is shown in Fig. 12.

Table 2
nRF24L01 module specifications

| Parameter | Value |
|---|---|
| Frequency Range | 2.4 GHz ISM Band |
| Maximum Air Data Rate | 2 Mb/s |
| Modulation Format | GFSK |
| Maximum Output Power | 0 dBm |
| Operating Supply Voltage | 1.9 V – 3.6 V |
| Maximum Operating Current | 13.5 mA |
| Standby Current | 26 µA |
| Logic Inputs | 5 V tolerant |
| Communication Range | Up to 800 m (line of sight) |


Fig. 12. Transmitter and receiver wiring between two Arduino–nRF24L01 pairs

On the transmitter side, the firmware reads the joystick and potentiometer positions along with two switch states, packs them into a compact PacketData structure (four byte-valued analog channels and two byte-valued digital switches), and writes the packet over the radio using the RF24 library's radio.write() call inside the main loop. The receiver runs a structurally identical sketch, listening for the same packet layout and using the decoded values to drive the ploughing motor speed/direction and any auxiliary actuators.

Where precise angular positioning is required for example, steering or tool-lift actuation, an MG995-type metal-gear servo motor (Fig. 13) is used. It is a high-speed, digital servo capable of rotating approximately 180° (60° in each direction), driven by a standard PWM control signal, and provides a stall torque of 10 kg·cm at 4.8 V and 12 kg·cm at 6 V.

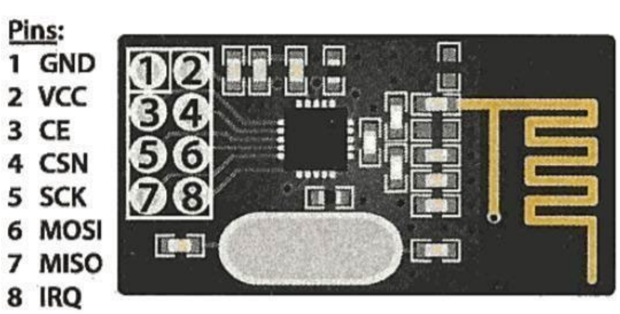


Fig. 13. MG995 metal-gear servo motor

Primary traction and ploughing-disc rotation are provided by a brushed DC motor, whose speed is regulated by pulse-width-modulated (PWM) signals generated by the Arduino Nano. Motor speed is set by the ratio of the applied voltage to the back-EMF developed as the armature rotates in the magnetic field; as this back-EMF is always slightly lower than the supply voltage, small variations in supply voltage or load translate into proportional variations in motor speed, which the Arduino compensates for through closed-loop PWM adjustment.

A potentiometer (Fig. 14) is used on the remote-control joystick assembly to provide an analog position/speed reference to the transmitter's Arduino Nano, which is then transmitted wirelessly to the receiver. A relay module (Fig. 15) provides electrically isolated switching for higher-current loads such as the ploughing motor, allowing the low-power microcontroller output to safely control the higher-current drive circuit.


Fig. 14. Rotary potentiometer used for analog position/speed reference

Fig. 15. Single-channel relay module used for motor load switching

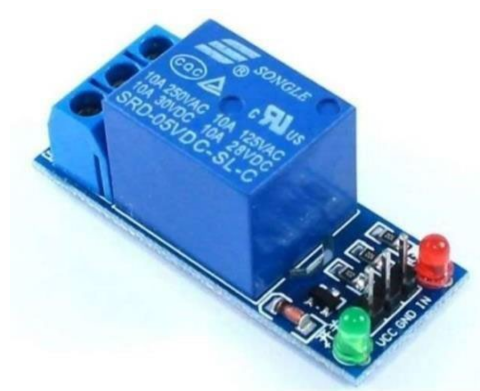


Fig. 16. 50 mm disc wheels used for chassis mobility

Four disc-type wheels of 50 mm diameter (Fig. 16) provide the machine's mobility; the wheels are coupled through an axle to the drive motor so that machine motion follows motor rotation directly-the machine advances as the motor and wheels rotate in the forward direction. The rotary ploughing discs are mounted on a separate shaft driven by the same power train, disturbing the soil as the chassis advances.

## 4. Results

A working prototype was assembled integrating the solar panel, charge controller, 12 V battery, Arduino Nano controller, nRF24L01 wireless link, DC drive motor, and rotary ploughing discs on a wheeled chassis. Testing confirmed that the machine could be driven forward and its ploughing motor engaged from a wireless RF remote at short range (up to the nominal 15 m design distance), with the DC motor speed varying smoothly under Arduino PWM control and the battery maintaining charge under solar illumination. These results indicate that a low-cost, remotely operated, solar-charged ploughing platform is technically feasible for small-plot agricultural use.

## 5. Conclusion

This work has presented the design, subsystem details, and prototype realization of a Remote-Control Solar Ploughing Machine intended to reduce the cost of cultivation while encouraging the adoption of cost-effective, eco-friendly farm mechanization. By combining solar charging, an Arduino Nano controller, and nRF24L01-based wireless RF control, the machine achieves zero-emission ploughing that requires no specialized technical training to operate. The prototype's front-wheel-mounted sensors additionally allow the machine to deviate around stones and other obstacles encountered in the field. With further development including government or institutional support for full-scale manufacturing this class of machine could offer a practical, low-cost alternative to diesel-tractor rental for small and marginal farmers.

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