The EDM How-To Book

by Ben Fleming

Fleming Publications
Disclaimer and License Agreement

The author of this book, Benjamin Fleming is NOT a professional engineer, nor has he had any formal training in the design of EDM (Electrical Discharge Machine/ing) technology or apparatus.

The designs found herein require the use of voltages and currents known to

KILL PEOPLE!

The said Fleming as well as the distributors of this publication assume no liability for injury to person/s or property that may result from the building, testing or operations of designs described in this publication. The intent of this publication is for

EDUCATIONAL PURPOSE ONLY

License agreement

By purchasing The EDM How To Book, it entitles the purchaser the right to build an EDM of this design for personal use only.

The design outlined in this text is not to be built and sold for gain or profit without agreement from the author, Benjamin Fleming. All violators of this agreement will be aggressively prosecuted.

In other words, you cannot go into business building this machine without my approval. If you want to do that, manufacture and sell your own design.
Contents

Preface .......................................................... vii
A brief EDM history ............................................ viii
Printed Circuit Boards ......................................... ix
Introduction ...................................................... x

Chapter 1 ......................................................... 1
Principles of EDM operation ................................. 1
Generator design .............................................. 3

Chapter 2 ........................................................ 6
Getting started ................................................... 6
The completed EDM schematic diagram ................. 7
Physical layout and brief overview of the generator .... 8
Understanding the control circuit operation ............... 9
Source of required parts ...................................... 10
Board population ............................................ 11
Bottom side of the PC board ................................ 12
Construction tips ............................................. 13

Chapter 3 ......................................................... 14
Control circuit wiring ......................................... 14
Installing the control board power supply ............... 14
Wiring the DIP sockets ....................................... 15
Connecting the control circuit to the Terminal Blocks . 19
Photos of the completed control circuit board .......... 20

Chapter 4 ......................................................... 21
Installing finishing capacitors and TB’s .................. 21
The complete generator schematic ....................... 22
Installing the coarse cut capacitor ....................... 25
The weakest link ............................................. 26

Chapter 5 ........................................................ 29
Generator box selection and preparation ................. 29

Chapter 6 ........................................................ 31
Positioning the rectifier and filter capacitor ............... 31
Selecting the transformer .................................... 32
Control board location ....................................... 34
Power resistors ............................................... 34
Front panel layout ........................................... 36

Chapter 7 ........................................................ 37
Panel meter option ........................................... 37
Wiring the meter into the generator circuit ............... 38

Chapter 8 ......................................................... 40
Wiring the generator and installing components ......... 40
Testing the primary transformers wiring ................. 43
Wiring and testing the transformers secondaries ....... 44
Wiring the rectifier and filter capacitor ................... 45
Testing the rectifier output voltage ....................... 46
Installing front panel components ....................... 46
Installing control board and resistor bank ............... 47

Chapter 9 ........................................................ 47
Final wiring and testing ...................................... 47
First voltage test of the control board ..................... 48
Wiring the rapid up down servo push switches ........... 49
Wiring the servo jack and LED ............................. 50
Wiring the coarse/fine capacitor switches ................. 51
The banana plug and TB9&10 connection ................. 52
Control board and power supply voltage test .......... 54
Voltage test of the LM-339 output’s ....................... 56
Testing the output of the servomotor driver ............. 56
Preface

I have seen articles published in the past on building an RC-type Electrical Discharge Machine (EDM) for home and/or small shops. Most of these designs, in my opinion, are far too complex. The intent of this book is to make available to the do-it-yourselfer my years of experience building very simple, yet highly effective automated, RC type machines.

Some of the topics covered in this book are:

1. Theory of the EDM process,
2. Explanation of circuit operation,
3. Building the generator,
4. Building an automatic control system,
5. Building a low cost, gearmotor slide
6. Building a dielectric tank and filtering system,
7. EDM techniques and tooling.

The book is laid out to construct the EDM in the following building sequence, though it may be built in any order.

1. Control circuit
2. Generator circuit
3. Servo head
4. Dielectric tank

Should any readers develop a more advanced EDM, I would be happy to correspond with you regarding its development. It is my hope that you will find this book interesting, as well as a valuable resource in your quest to know more about the EDM process.
A brief EDM history

The Russians are usually given credit for discovering the EDM process in 1943. Lazarenko is the name that is associated with the process first called Spark Erosion, more recently referred to as Electrical Discharge Machining (EDM).

In 1770’s, the English scientist Priestley discovered the eroding effect of electrical discharges. More than one hundred year was to pass before some practical use was made of the discovery.

During an investigation of how to suppress the erosion of electrical switch contacts, the Soviet scientists B. R. Lazarenko and N. I. Lazarenko had an idea. Why not use the destructive effect of the electrical charge in a controlled manner for machining recently developed metals that where proving to be difficult to machine. Soon thereafter, they developed a working procedure with spark erosion, where an electrical discharge in a dielectric liquid takes place between two conductors.

The Lazarenko’s developed what early on came to be called a Lazarenko circuit. Today it’s referred to as a relaxation, or RC circuit. It was used for a while in early commercial EDM designs. This particular type of generator is used even today in some EDM machines to obtain a near-mirror finish. The generator described in this book is an RC circuit based on the design developed by the Lazarenko’s.

Printed Circuit Boards

Many builders prefer a PCB (Printed Circuit Board) to speed construction, over the point to point wiring method, described in this book. Boards are available with instructions for $25 ea. (subject to price change) which included S&H (U.S. only). Payment maybe made via Paypal or Money order. See Appendix page 124 for more information.

All non-U.S. orders for PCBboards and Patent Book contact me for prices including shipping.

Benjamin Fleming
1734 N. Viewpoint Dr.
Fayetteville AR. 72701
E-mail
bfn@mail.uark.edu

EDM Patent Book available
I have copies of a book compiled from a Patent search of commercial EDM systems. The Book is titled:
EDM PATENTS 1960’s-1990’s they are available for $12, each which includes shipping. (U.S. only)

Yahoo support group
A Yahoo group is available to assist builders.
http://groups.yahoo.com/group/EDMHomEBuilders
Introduction

You can have EDM capabilities in your shop for a minimal investment of time and money this book will show you how. Many ask, why should I want another metal cutting machine when I have a lathe, mill, and other metal working tools? For one thing, EDM provides capabilities not provided by any other metal cutting methods. With this capability, it opens up moneymaking opportunities. One is the precision removal of broken taps and drills. It's possible to burn a broken tap, drill, or an "easy-out" from a piece of aluminum (or other metals) without touching the previously formed threads. Other practical applications are, the squaring of milled corners or burning odd shaped blind and through holes, even making cuts in carbide is possible with and EDM.

An example, suppose a seven-sided hole is needed in a piece of hardened steel. With a ram EDM, it is a walk in the park. For the artisan, carve your initials or a design on the end of an electrode (negative or positive) and then burn it into the workpiece. The EDM opens up a completely new world of machining capabilities; your imagination is the only limit, so go for it!

My introduction to the world of EDM (Electrical Discharge Machine or Electrical Discharge Machining) came at, of all places, a yard sale in 1982 when I purchase two boxes of old Popular Science and Popular Mechanics magazines. The basic theory of the process was described in one magazine, with details of how to build a manually operated EDM. I built the machine and became obsessed with the EDM process.

I soon discovered that these machines would cut anything that conducts electricity!! I had been exposed to machine tools in high school and at a technical college, but had never seen anything like this! From that meager beginning, the first attempts were made to find additional information on EDM design. Remember this was prior internet but it didn’t take long to discover that there is almost no information available to the public.

Many of you may have attempted to delve into the mysteries of the EDM generator and control circuits and found the same lack of published information. The large EDM manufacturers certainly are not going to tell you anything about generator/control circuit design. I know that from personal experience as one EDM company engineer told me, "the kind of information you are seeking is proprietary and only actively worked on by about 20 people in the U.S."

This book is, in part, an attempt to fill the EDM knowledge void. In this book, I will give hands on, step-by-step information needed to build a simple, low cost, automated EDM system. This kind of information is found in very few places. I spent about 2 1/2 years, and a lot of trial and error building my first automated ram EDM. Since that time, I have built many different versions of the EDM, including both RC (resistor capacitor) and with limited success, a more advanced pulse machine. My research on pulse machines continues and in the future, I hope to publish a book on building such a machine.
The photo below shows the finished EDM system described in this book. This is the setup used to burn the EDM logo (shown on the previous page and on the back of the book) into the file. You will be able to do the same thing once you finish building the EDM!

I have been asked about the Logo burn. Yes the actual machine described and shown in this book was used to make the cut. The logo is 3" long and 1" wide. It took 2 hours to burn to a depth of .062 using the 200uf capacitor setting. The dielectric was kerosene, and the jet flushing method was used.

All attempts have been made to ensure that no technical mistakes have been made in the text of this book. Should any readers discover short coming please advise so that future readers may have the most correct text.

Chapter 1

Principles of EDM operation

Electrical Discharge Machining (EDM) is a process that uses electrical discharges from an electrode to erode an electrically conductive material. As a result, it is possible to erode or “burn” the shape of the electrode into the workpiece. The drawing is a schematic of a typical EDM system. An EDM system is comprised of a generator, also known as a power supply, a servo system (servo and servo control), a dielectric tank, and filtration system. (NOTE: the term generator was used in the early days of EDM work. More recently it has been replaced with the term “power supply.” To minimize confusion during building the term generator will be used when it pertains to the high power section of the EDM power supply)

The workpiece is placed in the dielectric tank and affixed to a metal plate in the tank. The tank is filled with a hydrocarbon dielectric fluid (such as kerosene), which ionizes in the presence of an electrical field. The dielectric fluid breaks down electrically (i.e. conducts), after a short ionization period, assuming the electrical field intensity is high enough. The electric field is created by applying a voltage between the electrode and the workpiece (known as the gap). The breakdown of the dielectric fluid is much like
the breakdown of air when a large voltage is supplied from the coil in an automotive ignition system to the spark plug. However, in an EDM application the gap is typically held to only a few thousands of an inch, the applied voltage does not need to be very large for an EDM “spark” to occur. Typical operating gap voltages for EDM machines are in the range of 25-50VDC though the ionization voltage may be quite a bit higher.

The servo system maintains the appropriate separation of the electrode and workpiece as determined by the operator setting the desired gap voltage on the EDM generator. The gap voltage feeds back to the servo control system so that the proper separation of the electrode and workpiece may be maintained. As each spark discharges from the electrode (the cutting tool) to the workpiece, a small amount of metal is “vaporized” leaving a crater in the workpiece. The dielectric fluid rapidly cools the vaporized metal. The solidified metal particles, known as swarf, are removed from the work area by the circulating of the dielectric oil, and the filtering system traps the metal particles.

The EDM burning process is repeated thousands of times each second. As the workpiece is eroded away by the repeated discharges, the electrode descends under the servo control system. As a result of millions of electrical sparks melting small quantities of metal, it is possible to erode various shapes into any material that will conduct electricity, even some semi conductive materials may be machined via this process. Generally speaking, the hardness of the workpiece has little effect on the burn; this is one of the biggest advantages of the EDM process.

Some are concerned about the possibility of fire when using EDM equipment and a petroleum based dielectric fluid. It is essential that the end of the electrode (where the sparks are produced) always remains immersed in at least 1” of dielectric fluid. As long as the sparks are under

the fluid, the fire hazard is minimal. To start and maintain a fire you need three things: (1) heat, (2) fuel, and (3) oxygen. If any of these is missing, you will not have a fire. By keeping the sparks immersed, the supply of oxygen is eliminated and the fire hazard is virtually non-existent.

**Generator design**

The description below maybe a bit technical for those not familiar with electronic lingo, but hopefully you will be able to glean enough information to have a basic understanding of the different design concepts. The EDM generator is what controls the electrical discharges. It’s essential that between the discharges, the dielectric oil have time to recover. If this off time is too short, a dc arc will develop instead of a spark, this is bad, it will destroy the electrode and even the work piece. Should an arc occur the energy supplied by the generator will simply go into heating up the electrode, workpiece, and fluid, and not into eroding the workpiece material.

There are two basic types of EDM machines, RC (resistance-capacitance) and pulse. RC machines are rugged, simple to use, low in cost, and have good burn stability. The figure below (right) shows a block diagram of an RC machine. An RC machine consists of a DC supply, a series resistor, and a capacitor which is in parallel with the electrode, workpiece and gap. When the power is turned on,
the capacitor charges through the resistor and, eventually, the gap voltage becomes large enough to break down the insulating ability of the dielectric fluid. The stored energy in the capacitor rapidly discharges through the gap.

The figure (page 3) on the left shows a typical waveform of an RC generator. The waveform indicates the discharge time (t) is much shorter than the charge time (T). Each discharge is a single spark. The series resistance may be changed to vary the charge time, which will affect burn rate and burn stability. The amount of material removed for each spark depends on how much energy is stored in the charged capacitor.

The operator may have several capacitance, and resistances values that can be switched in and out of the circuit. The higher the capacitance, generally, the higher the metal removal rate. The disadvantage of higher capacitances is that the higher energy per spark creates a poorer surface finish on the workpiece because the crater size is larger.

Some people speak bad of RC type EDM machines because of the increased erosion rate on the electrode. I will agree, it is quite a bit higher than with the newer designed pulse machines, but it is not nearly as bad as it used to be. The main reason for the improvement is the higher quality electrode materials available now. This is true in particular with the available graphite electrode material. I recommend using graphite electrodes with the RC machine described in this book.

Today virtually all commercially EDM designs are pulse but I have seen pulse machines built in the late 90’s that had RC finishing generators built into them. RC machines maybe old school, but there are situations where they are the best choice. The drawing on page 5 (right) shows a block diagram of a pulse system. The corresponding gap voltage waveform is shown (to the left). A solid-state switch (i.e. transistor or fet), switches power on and off to the gap. Once the solid-state switch closes, it takes a short period of time for the dielectric oil to ionize and then the discharge takes place, the discharge continues as long as the switch is closed.

For pulse systems, the surface finish is controlled by adjusting the on time, and the current level. Although quite a bit more complicated than RC designs, the big advantage of a pulse power supply is that electrode wear can be greatly reduced under certain machining conditions. Metal removal rates improve due to the long on times i.e. the pulse machine is more efficient than the RC design. The primary disadvantage of pulse systems compared to RC systems, is that the burn in some cases tends to be less stable especially under poor flushing conditions and (this is a big one) they require a much, much more sophisticated and expensive control system to give good performance.

For a small home shop, and even small machine shops where the EDM is used occasionally for odd jobs, the simplicity of design and much lower cost of the RC generator usually outweighs the disadvantages. The machine outlined in this book is an RC design. Should there be sufficient demand, perhaps later writings will include a pulse design EDM machine.
Chapter 2

Getting started

I anticipate that there will be more machinists with minimal electronic experience attempting to build the EDM, than there will be electronics persons with minimal machining abilities. Assuming this is the case, I give a detailed step-by-step description of how to build the control system and generator. In case you missed it, to make things easier a PCB (Printed Circuit Board) is available, see Page ix in the front of the book and Page 124 in the Appendix. This greatly simplify the electronic wiring. With the PCB and parts in hand it takes less than an hour to build and test, plus you can skip the instruction given on pages 11 thru 28!!

For those who elect not to use the PCB you should be able to successfully complete the project if you can,

1. Follow written instructions closely
2. Perform sound electrical connections on a generic P.C. (perf type) board
3. Are able to understand simple electrical schematics
4. Understand how to use a VOM/multimeter

If you are not that familiar with reading schematics, a little time in the library or, on line, brushing up should prove helpful. Reading schematics can be a little tricky; for example, connections shown on schematics are not necessarily how they are physically wired. The schematic shows only how the circuit is “electrically wired.”

In the Appendix of the book you will find a list of parts (electronic/mechanical) which are needed to build the EDM.
Physical layout and brief overview of the generator

All of the electronics required for the EDM are located in an electronic project box. The photo below shows the placement of the major components in the EDM cabinet.

The AC output of the two large transformers (1&2), is rectified (back right-hand corner) and filtered to smooth DC power. Two power resistors are mounted in the front (left hand corner) of the enclosure. The control board (non-PCB in this photo) is located in the front right hand corner and receives it power from the small transformer (3). The control board contains the low voltage power supply as well as the actual control system. This board also has the finishing and coarse cut capacitors mounted on it.

The availability of IC's (integrated circuits) makes it possible for a person with minimal electronic knowledge and skills to build a very powerful control system for an EDM machine. A tremendous amount of electronics get packed in the small IC's; the only items needed to control the IC circuitry are a few external components, which you will be adding.

Understanding the control circuit operation

The control circuit, see schematic page 10, is a window comparator circuit built around a LM 339 IC (integrated circuit). This IC chip samples the voltage drop across the EDM gap (points “A” and “B” right hand side of schematic. See points “A” and “B” on the complete schematic page 7) and then compares that to a reference voltage, that’s manually set by the operator, adjusting reference pot. R5 on the panel. Should the gap voltage be higher or lower than the reference voltage, a signal is sent to the servomotor driver chip (SN754410NE) to advance or retract the electrode.

The electrode movement is accomplished via a DC servomotor positioning a ball slide, to which the electrode is attached. Once the gap voltage and the reference are the same, a null occurs. In this condition, the EDM generator continues to apply power to the gap, but the servomotor control system does not energize the motor. As the workpiece “burns” away, a physically larger gap between the electrode and the workpiece results. The larger gap requires a higher voltage to continue the burn. The control system senses the elevated voltage (drop) and advances the electrode, until the reference voltage and gap voltage come into an agreement.

Should an electrical short occur between the electrode and workpiece the gap voltage will drop below the reference voltage. The comparator signals the servomotor to mechanically retract the electrode, i.e. break the short. Once broken, the gap voltage is higher than the reference. The servomotor physically advances the electrode until and are is established and the gap voltage and the reference reach the afore mentioned null.
In this text, the copper trace side of the board is referred to as the bottom of the board. Before soldering, rub the copper traces with steel wool to clean the copper; this prepares it to receive the solder. If you are not familiar with soldering electrical connections on PC boards, I suggest purchasing a second (sacrificial) board and practice soldering. If to much heat is applied to the copper traces they will release from the board.

**Board population**

The process of installing electronic components on the board is called **populating the board**. How the board is populated is up to the individual builder. The photo below shows an overview of the major components of the control circuit. The description in this book will be based on this board layout. Along the left hand side of the board are the four (eight actual connections points) PC board **Terminal Blocks** that provide a means of connecting most of the control circuit to other parts of the EDM system.

The 14-pin DIP (Dual Inline Package) socket for the LM 339 comparator, is located in the lower left hand section of
the board. Above this, is the 16 pin DIP for the
SN754410NE servomotor driver. Immediately above the 16
pin DIP are three components. The first, in a rectangle
package, is a 12VDC regulator. Just in front of the regulator,
is a round 1000μF 35VDC filter capacitor. The small round
black package to the right is a 1.5 amp silicon bridge rectifier
that delivers DC power for the control system and
servomotor.

Bottom side of the PC board

The photo below shows the bottom side of the board
with two types of copper traces visible. There are traces with
three holes in each trace. In the text, I refer to these as
"stand-alone-three-hole trace". These traces are not
connected to other traces. There are two longer traces that
are not connected to each other or the stand-alone traces, but
run around the outside, and through middle sections of the
board. These traces connect to the positive (+) and negative
(-) side of the low voltage power supply that is mounted on
the board.

The traces forming the “T’s”, as seen in the photo at
points B, C, D, and E (etched in copper on the board), will be
the positive (+) trace. On the top side of the board, the
screened white lines indicate these traces. The other traces
(parallel to the positive) which form “T’s” on the opposite
end of the board, is the negative (–) trace.

Construction tips

1. After each solder connection is made, visually inspect the
board (under a magnifying glass, if necessary) and make
sure, only the traces and components that are meant to be
connected are the ones actually soldered. Make sure that
bare wires are not exposed to points not intended to be
connected. Pay particular attention that the + & - traces
are not shorted together.

2. Continually check that the correct pins are connected on
the IC sockets. Have a second person verify the
connections. This attention to detail will save MUCH
heartache in troubleshooting later.

3. Before each task, a [ ] box will be found. Once the
operation is performed place an [X] in the box. This will
assist in making sure all required tasks are completed.

4. An excellent source for uninsulated jumpers is the clipped
ends of component leads.

5. Use “solder wick” (also known as desoldering braid) to
remove excess solder, should a solder bridge occur.
Chapter 3

Control circuit wiring

[ ] During the building phase, the DIP sockets **should not** have the IC chips in them.

[ ] Begin populating the board by inserting both the DIP sockets into the board with the small notch (or dot) in the sockets facing the left side of the board.

[ ] The 14 pin DIP straddling power traces at “B”, see the photo (to the right).

[ ] The 16 pin DIP straddles the traces at “D”.

[ ] Solder all the DIP pins to the stand-alone-three-hole traces as seen in the photo.

[ ] TB (Terminals Blocks T1-8) are inserted along the left side of the board. The TB’s have a locking tongue and groove system that mate with the adjacent terminal. Make sure these are matched and locked in place before soldering.

**Installing the control board power supply**

The schematic see page 15 (right) is of the power supply on the control board. The next item to install is a 7812 twelve-volt regulator (U1) Radio Shack (276-1771). Looking at the regulator from the front (black plastic side) the pins from left to right are Input, Ground, and Output.

[ ] Bend the pins of the regulator so that the legs go into the following traces, see photo above. The **Input** pin goes in a stand-alone three-hole trace; the **Ground** pin goes in the negative (-)trace, and the **Output** pin goes in the positive (+) power trace (at location “E”) solder all in place.

[ ] Immediately in front of the regulator, the 1000uf filter capacitor (C5) is placed in the board. This component is **polarity sensitive**, the negative (-) leg (indicated on capacitor side) must be in the negative (-) trace. I used the most outboard negative trace. The positive (+) leg of the capacitor shares a common stand-alone-three-hole trace with the **Input** leg of the regulator, solder in place.

[ ] Place the (D2) rectifier to the right of the filter cap. and regulator. The two AC and the positive (+) leads (noted on the case) go into separate stand-alone-three-hole traces. The negative (-) lead goes to a (-) trace, solder in place.

[ ] A jumper goes from the cap./regulator (common) stand-alone-three-hole trace to the positive (+) lead of the rectifier.

**Wiring the DIP sockets**

Both DIP sockets are numbered CCW (counter clockwise) when viewing the socket from the **top side** of the board.
caution do not confuse the pin numbers as you turn the board over to make solder connections. This is a VERY EASY mistake to make.

[ ] Pins 4, 5, 6, & 7 go to the negative (-) trace.

[ ] Pins 1, 2, & 12 connect to the negative (-) trace.

[ ] Pin 3 attaches to the positive (+) trace.

[ ] Solder a .1 Cap. from pin 3 to a negative (-) trace.

[ ] Solder a .1 Cap. from pin 11 to a negative (-) trace.

[ ] A 4,700 (4.7K) resistor (R12) goes from pin 8 to a negative(-)trace.

Upgrade note: as of this 4th printing capacitor C9 has been added and the value of R11 and R12 have been changed to 6.8K and 4.7K respectively. This provides a significant improvement in operational stability. The simplest approach is to follow the schematic and use a fixed resistor as shown in the schematic above.

Optional, those more electronic savvy the window resistor (R11) maybe a panel mounted10K pot and a series 1K ohm resistor see schematic above left. By panel mounting the pot. the “window voltage” of the gap can be easily adjusted to help stabilize the burn during difficult EDMing conditions.

[ ] A 6.8K (R11) resistor connects between pins 8 & 11.

Radio Shack does not sell a 6.8K resistor, but a (271-1330) (4.7K) ohm resistor will work almost as well. To give you an idea of what I am talking about, in prior book printing this resistor was only 1K and it worked OK, anything larger than the 1K resistor is a significant improvement in burn stability.

[ ] Next, jumper between DIP pins 9 & 10.

[ ] Solder the 6.8 uf capacitor (non Radio Shack) from pin 10 to a negative (-) trace.

Next, the wiring of the 16-pin servomotor DIP socket is accomplished. See schematic below.

[ ] Pins 4, 5, 9, 10, 12, 13 & 15 go to the negative (-) trace.

[ ] Pins 11, 14 float i.e. they are not connect to any traces

[ ] Pin 16 (servo DIP) solders to a positive (+) power trace.

[ ] Solder a .1 Cap. from pin 16 to a negative (-) trace.
[ ] Pin 8 goes to the positive (+) side of the rectifier, not the output of the voltage regulator, or a positive (+) trace, see schematic above.

[ ] A 33,000 (33K) ohm “pull up” resistor (R6) goes from pin 1 (servomotor DIP) to a positive (+) trace.

[ ] A 33,000 (33K) ohm “pull up” resistor (R7) is soldered between pin 2 and the positive (+) trace.

[ ] A 33,000 (33K) ohm “pull up” resistor (R8) connects between pin 7 (servomotor DIP) and the positive (+) trace.

[ ] Run a jumper from pin 14 on the comparator DIP socket to pin 2 on the servomotor DIP socket, see schematic.

[ ] Solder a jumper from pin 13 on the comparator DIP socket to pin 7 on the servomotor DIP socket.

Your board should look similar to the photo below.

Connecting the control circuit to the Terminal Blocks

In the next operations, connections are made from board mounted components to the TB (TB1-8) along the left hand side of the board. I refer to the terminals in ascending order with terminal number 1 being in the lower left hand corner of the board as viewed from the top. See schematic (page 18) for an understanding of the wiring. The way the TB’s and board are designed, it’s necessary to run many of these connections on the trace (bottom) side of the board.

[ ] From TB1 run a black plastic insulated wire to any negative (-) trace on the board.

[ ] From TB2 a connection is made with a red plastic coated wire to any positive (+) power trace.

[ ] From TB3 a jumper goes to pin 10 (pins 10 & 9 should already be soldered together) on the comparator DIP.
Chapter 4

Installing finishing capacitors and TB's

As with most things, I have made some compromises in the generator design to accommodate space, cost, and simplicity. The end product is a simple, yet rugged design that will work fine in the home shop as well as many small job shops.

Photos of the completed control circuit board

Now that the low voltage control circuit is finished, the next task is to build the actual high voltage generator section of the EDM.

The capacitors, which store the “cutting” charge, as well as the Terminal Blocks used to connect the capacitors to the rest of the generators circuit, are physically located on the PC board. The photo above shows the completed board with all components mounted. The EDM finishing circuit is composed of two (large) 20uf “finish cutting” capacitors, located on the back right corner. See page 22 for the high voltage generator schematic, it shows the TB’s, meter circuit, and the capacitors on the circuit board.
Two finishing capacitors are used to give a wider choice of surface finishes and speeds when doing finishing cuts. The two capacitors are not available via Radio Shack or Allied. The only economical source I know for the preferred capacitors is Parts Express see Appendix. Parts Express also sells the same type of polypropylene capacitor in different uf ratings. The smaller the uf caps. used the finer will be the finish surface on the metal. I do not recommend going below 5uf with this particular control circuit design.

[ ] Insert one lead of each 20uf capacitor (C1 & C2) into a negative (-) trace.

The capacitor placed closest to the bridge rectifier is capacitor C1, the one adjacent it, near the board’s edge, is capacitor C2. The orientation of the capacitors is not critical (they are not polarity sensitive). The other lead of the capacitors are bent over the top of the capacitors and inserted into individual stand-alone-three-hole traces. It’s necessary to extend the length of this lead in order to make the connection; see photo on page 21.

[ ] Solder all the leads to the traces to hold everything securely in place.

[ ] Solder the leads of the capacitors in the negative (-) trace together so that they are parallel. The capacitor leads are soldered together so the current pulses (during the capacitors discharge) are carried primarily via the capacitors leads, and not by the thin copper traces which could possibly burn apart like a blown fuse. The two leads going to the stand-alone-three-hole traces are not connected together.

The next step is to mount a single Terminal Block TB9&10 on the extreme right hand side of the board, just below the finishing capacitor C2; see the following photo.
TB9 is positive (+) and TB10 is negative (-). In the finished wiring, both sides of this TB connect directly to the gap.

[ ] Insert one leg of the TB 9&10 into the negative (-) board trace. On the Radio Shack PC board, this connection will be (TB10) located on the right hand side of the board as viewed in the photo above. Mark the board to indicate the polarity of this side of the connector. The other side of the Terminal Bock, (TB9), goes into a stand-alone-three-hole trace.

[ ] Solder the negative lead (or a jumper) from one of the parallel connected finishing capacitors, to TB10, the negative (-) side. (The negative side of both the high and low voltage power supplies are electrically at the same potential, this is the connection that ties the generator circuit and the control circuit together.)

[ ] TB9 has two connections made to it, both connections are located on the bottom side of the board.

[ ] The first of these two connections is a jumper wire, which connects to capacitor C2’s stand-alone-three-hole trace. If properly positioned TB9’s positive (+) lead is inserts into the stand-alone-three-hole trace used by the capacitor, thus eliminating the need for the jumper. Finish capacitor C2 is always connected across the gap, see schematic on page 22.

[ ] The second connection to the positive (+) side of TB10 (not shown in the schematic on page 22 but is shown in the schematic on page 18) is a 100,000 (100K) ohm resistor (R10), which solders to terminal 11 on the comparator DIP. In most cases, the resistor leads will not be long enough to reach the Terminal Block. Either lengthen the lead, or solder the resistor into an empty stand-alone-three-hole trace. Then jumper from that trace to the TB9 trace. Be sure and insulate the leads to prevent any possibility of shorting.

Installing the coarse cut capacitor

Capacitor C3, needed for making coarse EDM cuts, is not available via Radio Shack or most other electronic supply houses. Unfortunately, I do not have a reliable source to refer you to for purchasing this capacitor. If possible, this electrolytic capacitor should be a photo or strobe flash capacitor. Radial leads are preferred to make mounting simple and to conserve board space. The ratings should be a minimum of 100VDC @ 80 uf. A higher voltage and capacitance is better, but usually means the capacitor will be larger. The one I am using is 200VDC @ 160 uf.

The All Electronic Corp. frequently has these capacitors in stock. If not available, keep checking back with them.

All Electronics Corp.
1-888-826-5432
http://www.allelectronics.com
Another option, and perhaps the best, is to use a photo flash capacitor from a disposable 35mm camera. I picked up a couple of the empty cameras free from the local photo developer. The capacitors I retrieved from these camera’s were rated for 160 uf at 330VDC. They charge to 300VDC in the camera. If you choose to use these capacitors make sure they are fully discharged, most I have found are in the charged state in the camera. Short across the leads before removing them from the camera, other wise you could be in for a real shock!

The weakest link

By using an electrolytic photo flash capacitor, it is possible to have a “high uf rated capacitor” that has proven to work well in this application; it is cost effective and yet small enough to mount on the board.

Most all electrolytic capacitors that I know of, even the photos flash (or strobe flash) capacitors, are not really designed for this particular application, and many times they will be pushed to their limits and beyond. There is always the potential that the electrolytic capacitor will heat up and fail, even rupture. I have built quite a few of these small EDM machines and have only had one photo flash capacitor fail. Proper cooling is paramount when using these capacitor. As discussed later a cooling fan must be used on the EDM. I feel using these capacitors it is a justifiable risk to take, to reduce the cost and size of the EDM.

The C3 photo flash capacitor is mounted near the LM339 comparator; see photo on page 27. This leaves a void on the right hand side of the board, for the optional panel meter (see Chapter 7).

Mount the C3 electrolytic photo flash capacitor on the board. Remember, it is polarity sensitive. Make sure the negative (-) lead is inserted into the negative (-) trace and the other lead goes into a stand-alone-three-hole trace.

Use a short length of insulated wire (at least the diameter of the capacitors leads) to jump the negative (-) lead of the photo flash capacitor to the negative (-) leads of C1 & C2 finishing capacitors, or it may be connected directly to TB10, electrically it is the same point.

To the right of the photo flash capacitor, install TB 13&14 as shown in the photo above. The two terminals should be soldered into two individual stand-alone-three-hole traces. It is through this Terminal Block that the coarse and fine cut capacitor switches are connected.

Connect the positive (+) lead of the photo flash capacitor to TB14 closest to the photo flash capacitor as seen in the photo. Mark this terminal polarity (+), for future reference.

The other side of the terminal is TB13. It’s connected via an insulated jumper to the stand-alone-three-hole trace of finishing capacitor C1.
At this point all finishing and coarse cutting capacitor are connected. This completes all the wiring need for the board. Later it will be tested.

From the first time I saw an EDM machine I wanted to build a simple 10 amp unit that would fit in a shoe box. Granted this is not a 10amp machine but when you consider that the complete control circuit and a large part of the EDM generator are located on this small board that virtually anyone can build I think it is quite remarkable, see photo of completed board below.

---

Chapter 5

Generator box selection and preparation

I suggest you read completely through his sections before drilling or cutting any holes in the box. I was shocked at the prices being quoted ($50+) for boxes. If you know of a better selection for a reasonable price, please contact me.

NOTE: I found one box of the minimum size required (3 1/2x6x10) with an acceptable price tag. A second larger box (4x7x12), makes building much easier (see Appendix page 126). This project is built in the smaller box, in hindsight, I would have preferred the larger of the two boxes. If you can afford the increase price, get the larger box, or better yet fold up your own box, or recycle an old computer cabinet.

A suggested layout of the box, including the top of the box, is shown in the photo on page 30. Before drilling or cutting any of the mounting holes in the box it is a good idea to have the components in hand to actually measure and verify the required size. No components are mounted permanently in the box at this time, but components should be positioned in the box to verify locations.

[] Work starts on the box top. In the front left hand corner, cut a hole to permit the 3” Radio Shack (273-242) cooling fan. The fan bolt pattern is square 2 13/16 center-to-center holes. I cut a 2 7/16” (approximate) square vent hole with a pair of tin snips. The fan mounts over this hole.

[] Approximately 1/2” behind the fan (on centerline with the fan), drill a 5/16” hole to accept the grommet through which the fan power wires pass into the box interior.
Mount the fan on the box top with four 6-32 screws.

On the right hand side of the cover, drill twenty-four 5/16 holes as per the drawing on page 30. This forces air to flow through entire generator before exiting.

Mark and drill three holes on the left hand side of the box rear, as seen in the drawing below.

The 115V Radio Shack (275-603) SPDT on-off switch mounts in the top hole. A Radio Shack (270-362) panel mounted fuse holder in the second hole. The bottom hole accepts either a plastic strain relief or a vinyl grommet, Radio Shack (64-3025). A 115VAC Radio Shack (61-2859) power cord enters the generator box through this last opening. DO NOT drill the small 9/64” rectifier-mounting hole at this time.

**Chapter 6**

**Positioning the rectifier and filter capacitor**

The generator requires a hefty filter capacitor (C4), which is not available from Radio Shack. The capacitor used should be rated for at least 160VDC and 450uf. Do not substitute a smaller capacitor. More capacity is good, but it must physically fit in the space. I am using a radial capacitor (160VDC 1000) purchased from Allied (see Appendix).
The filter capacitor (C4) is placed vertically against the back wall, to the right of the AC power switch and fuse holder; see above photo. The actual physical location of the bridge rectifier is determined by the height of the selected filter capacitor. The rectifier is a Radio Shack (276-1181).

If the specified Allied filter capacitor is used, drill a 9/64 mounting hole approximately 1 9/16” above the box bottom. Otherwise drill a hole about 1/2” above the top of the selected capacitor to mount the rectifier via a 6-32 screw.

**Selecting the transformer**

In my opinion, an almost ideal transformer for a small EDM application would be a single transformer capable of delivering at least 70-75VAC at 5 amps or higher. The transformer should also have a separate 12VAC winding to supply power to the control circuit.

Lacking the preferred transformer, two Radio Shack (273-1512) 25VAC CT (2.0 amp) transformers were chosen (transformers 1 & 2 in photo (page 33) are T1 & T 2) The small Radio Shack (273-1365) transformer (T3) supplies power to the control circuit. The large power transformers are wired in series, on the secondary side, to obtain the required voltage.

If the Radio Shack transformers are used, follow the dimension on the drawing drill the transformer mount holes out to 13/64”. The center bolt captures both transformer’s overlapped feet, see photo below.

With components in hand verify hole locations then drill as required. I recommend standing transformer off the back wall about 1/8” (wiring run and cooling).

The drawing below shows the bottom of the box and a suggested dimensioned layout for the Radio Shack parts.
The small control transformer T3, is turned 90 deg. and stands off the power transformer about 3/8”, see drawing.

**Control board location**

The control board is located in the front right hand corner of the box on four Radio Shack (276-1381) standoffs.

Should you decide to install a meter (optional), see Chapter 7. The exact board location is determined by the needed clearance for the meter chosen. If an analog meter is **not used**, the dimensions on the drawing will be correct for the four 1/8” holes to mount the Radio Shack board.

**Power resistors**

The two 20 ohm 50watt silicone fixed power resistors see photo, (R1 & R2) used in the generator are connected in parallel forming a 10-ohm 100-watt resistor bank. Two resistor and two mounting kits, are required. The resistors may be purchased from Allied Electronics (see Appendix)

[ ] Cut the threaded mounting rod to a five inches length.

[ ] Assemble the resistors on the mounting hardware. Space is at a premium if the small box is used, so turn the mounting legs inward placing the mounting bolts holes under the resistors.

[ ] Position the assembled power resistors in the box to verify the four mounting hole locations as per drawing below.

[ ] Drill holes for mounting the power resistors.

To provide for the removal of heat generated primarily by the resistors, vent holes are needed in the bottom of the box.

[ ] As per the drawing below drill twenty-four 5/16” vent holes in the box bottom.

[ ] Deburr all holes or a nasty cut may result.

[ ] The power resistors connect in parallel using two 6-32 screws. This will eliminate the possibility of solder joint failure as the resistors heat up.
Front panel layout

The controls on the front panel maybe mounted in any configuration pleasing to the builder. The photo below and the drawing on page 37 show the layout I chose. The switches (starting in the upper left hand corner of the box) from top to bottom, and left to right, are as follows:

1. Coarse capacitor switch (SW3) Radio Shack (275-324).
2. Reference potentiometer (R5) 50K ohm Radio Shack (271-1716). A Radio Shack knob (274-402) for the shaft.
3. Servo rapid up switch (SW5) Radio Shack (275-1547)
4. Servo rapid down, switch (SW6) Radio Shack (275-1547)
5. Finish cut capacitor switch (SW2) Radio Shack (275-324)
6. Red positive (+) power out Radio Shack (274-725)
7. Black negative (-) power out Radio Shack (274-725)
8. The servo on off switch (SW4) Radio shack (275-324)
9. Servo LED (Light Emitting Diode) holder Radio Shack (276-079), the Led is a bicolor (D3) Radio Shack (276-012)
10. The servo output power jack (J1) Radio Shack (274-246) is a three-conductor 1/8” stereo audio panel-mount jack. This MUST be a normally open jack. The plug that goes into the jack is a three-conductor 1/8” stereo Radio Shack (274-284).

[ ] Layout the box as per drawing below and drill the required holes. Be sure and verify the sizes with components.

[ ] Install four rubber feet Radio Shack (64-2346) to the four corners of the box bottom. This is a must, it lifts the box and provide good air flow for cooling.

[ ] Before the final wiring of the generator, decide if a meters to be used. If so drill holes as required by the meter

Chapter 7

Panel meter option

As previously indicated, the analog panel meter is not needed for successful operations of the EDM machine. Should you install a meter and the small enclosure box is used, the mounting hole locations in the front panel are
critical, there is a potential interference problem with the control board if the meter is mounted too low. At the present time Radio Shack sells an affordable analog meter (Radio Shack 22-410). I don’t know how long they may carry it. Reasonably priced meter are frequently sold by surplus electronic suppliers (see Appendix) the problem is that their inventory is not consistent.

To fit a meter to the particular project box the meter selected should be approximately the physical size indicated below. Once purchased, it’s up to you to determine the size and location of the hole to cut in the box front panel. The specification for the meter I used is as follows.

Physical size 2 3/4 x 2 1/4 x 1 7/8”
Full Scale Value 15VDC
Internal Resistance 85 ohms

Some individuals make custom calibrated faces for the meter. In the Appendix (page 123), you will find two meter faces that are compatible with the suggested Radio Shack meter. Photocopy the face at 100% then cut out and very carefully glue it to the meter face behind the needle. Exercise care the needle is a fragile movement. Mechanically zero the meter (small screw in meter front) after installing the new face. Using this face-changing method and the potentiometer calibration suggested above, it is possible to adjust the meter to read virtually any voltage you wish.

**Wiring the meter into the generator circuit**

The meter is connected to the generator via a voltage divider R13 see schematic on page 7. The meter reads a voltage drop across the voltage divider. It is almost impossible for me to give you resistor values for the divider network, as I do not know the specification for the meters that may be used. Might I suggest a simple approach that should work for most meters with specification similar to the Radio Shack meter.

[ ] Purchase a small 100,000 ohm potentiometer, Radio Shack 271-284 or similar. The potentiometer will have three legs. Solder these into three individual stand-alone-three-hole traces.

[ ] Next to pot. R13 solder TB11&12 into two individual stand-alone-three-hole traces.

[ ] A jumper from the two outside legs (R13) connect to TB9&10, (which was previously mounted on the board).

[ ] The center leg (wiper) requires a jumpers to TB12.

[ ] A 33,000 (33K) R14 resistor between TB10 and TB11

[ ] Use a VOM, measure between TB11&12. Rotate the potentiometer to get a maximum resistance reading.

[ ] On the back of the meter it should indicate positive (+) and negative (-) terminals. Between TB11&12 connect the meter. The + side of the meter connects to TB12.
Once connected, momentarily turn the AC switch on. If the meter swings up scale, the connections are correct. If the needle swing to the left, the meter need to be reversed.

Turn the AC switch on and slowly rotate the pot. knob until desired scale deflection is indicated on the meter.

One of the problems with using a potentiometer in the meter circuit is, after a period of time, the wiper on the potentiometer could collect dirt, especially in a machine shop environment. This may cause the meter to give erratic readings; a fixed resistor avoids this problem.

**Chapter 8**

**Wiring the generator and installing components**

It is time to permanently wire the generator components.

Begin by soldering the center terminal (assuming the Radio Shack switch spec. is used) on the AC power switch (SW1) to either one of the adjacent terminals, effectively making this switch a SPST switch

**NOTE:** Some may wonder why I chose a SPDT switch. The particular Radio Shack (275-603) SPDT switch was chosen because of a space limitation in the small box used for the EDM. The correct switch would be a SPST of the proper size. If the larger box is used a larger standard AC switch such as Allied 757-4021.

Mount the power transformers T1 & 2 securely in the box with three 6-32 screws and nuts. Position the transformers so the black primary wires face the back wall.

Mount the control transformer, T3, with two 6-32 screws. The black primary wires should face the power transformers.

Transformers T1 & 2, clip off (close to the transformer) and save both black center tap wires

The 6A rectifier (D1) is held securely on the back panel with a 6-32 screw; see above photo. To aid in heat dissipation sand all the paint from the case in the area that will have contact with the rectifier. Apply Radio Shack (276-1372) or similar, heat-sink grease for good thermal contact.

Note which terminals are AC and DC on the rectifier; these markings may not be visible once mounted.

Install the AC switch (SW1), the fuse holder (F1), and the AC power cord grommet in the rear panel.

Cut the female end off a Radio Shack (61-2859) AC power cord. Strip the covering back about five inches, exposing the three inner wires.
[ ] Cut and save a two-inch length from the end of the black (or blue) wire.

[ ] Strip the black and white (blue and brown) wire ends back 1/2", exposing the wire. Strip the green wire back about 1".

[ ] Thread the cord through the panel grommet, and tie a knot to act as a strain relief (if a strain relief is used, the knot is not necessary).

[ ] Secure the green wire under a screw holding the transformer in place.

[ ] Solder the hot side, the black wire (or blue) of the line, to the fuse terminal.

[ ] From the remaining terminal of the fuse holder (F1), solder an insulated jumper, (using the previously cut black transformer center tap wire), to one of the terminals on the AC switch.

[ ] The (black) primary wires from each transformer connect in parallel see schematic on page 41. Pull the black primary wires from transformers T1 & 2 forward; make sure the wires from each transformer are not crossed. Select the left most wire from each transformer; twist these together. Select the remaining two primary wires and twist them together.

[ ] The (black) primary wires from transformer T3 also connect in parallel with the primary power transformer wires. There are three primary transformer wires going to each side of the AC line.

Might I suggest that all the 115VAC connections be covered with heat shrink tubing (Radio shack #278-1627) to keep a clean look in the box. An alternative is to use screw-on wire nuts (Radio Shack #64-3057).

[ ] If using shrink tubing, slide it over the wires and solder one set of three (transformer) primary wires to the AC line. Do not put heat shrink in place yet.

[ ] The black center tap wire (saved earlier) solders to the AC switch lug and connects to the remaining bundle of three black primary transformer wires. Do not put heat shrink in place yet.

[ ] After the solder joints are cool, slide the heat shrink tubing (or wire nuts) over the connections to insulate them. Do not shrink the tubing in place at this time.

[ ] Install a 2-amp Radio Shack (270-1023) fuse in the holder.

**Testing the primary transformers wiring**

This test will insure there are no short circuits in the wiring.

[ ] Make sure that the secondary wires from the transformers do not touch each other or any part of the generator box.

[ ] Check that the short stubby black center tap wires are not making electrical contact with the case.
BEFORE PERFORMING THIS TEST, (OR ANY TEST WHERE THE GENERATOR CASE IS OPEN AND ACCESS TO 115VAC IS POSSIBLE) CAREFULLY THINK THE TESTING SEQUENCE THROUGH BEFOREHAND. MOVE SLOWLY, AND USE ONLY ONE HAND. AFTER THE TEST TURN THE AC SWITCH OFF AND UNPLUG THE GENERATOR.

REMEMBER AC POWER CAN AND WILL KILL YOU!

[ ] Plug the generator in and turn on the AC for five seconds.

[ ] Turn off and unplug the AC cord.

[ ] Verify that the fuse is not blown. If it is, there is a problem with the wiring. Go back and check the wiring.

[ ] Do not proceed with the generator wiring until the problem has been resolved.

Wiring and testing the transformers secondaries

[ ] Strip the insulation back 1/2” on the four yellow secondary wires from T1 & 2 transformers.

[ ] Observe the physical sequence of the wires that emerge from the secondary side of the transformer housing. It should be yellow, black (center tap stub) yellow. The second yellow wire on transformer T1 is temporarily connected to the first yellow wire from transformer T2.

To check that this connection is correct, a voltage reading is taken using a voltmeter (VOM) more commonly known today as a multi-tester or multimeters. Low cost meters that perform all the test needed in building the EDM machine, are available from most hardware and home improvement stores; prices range from $10 up. I prefer the digital meters as they give you a precise, “no questions ask” reading.

[ ] Make sure that the remaining wires from the transformers do not touch each other, or any part of the generator box. Set the VOM on the AC range, at least 100VAC.

[ ] Using alligator clips (Radio Shack #278-001), connect the VOM leads to the two remaining transformer yellow leads.

[ ] Plug the AC cord in, and turn the AC switch on; the VOM should read approximately 56VAC. If not, the outside-most wire on transformer T2 needs to be connected to the inside-most wire on transformer T1. Do not proceed until the desired voltage, approximately 56VAC, is read.

[ ] The temporarily connected common wire to each transformer is now permanently connected together, via soldering and shrink tubing, or wire nut.

Wiring the rectifier and filter capacitor

[ ] MAKE SURE THE UNIT IS UNPLUGGED!! Bend the DC leads, from the rectifier (D1), in such a fashion that they are able to be soldered to the respective terminals of the filter capacitor (see photo on page 41). The negative (-) terminal is connected to the negative (-) terminal of the capacitor; the positive (+) terminal connects to the positive (+) terminal of the capacitor. The filter capacitor (C4) is actually held in place by the rectifier leads soldered to the capacitor terminals or to two holes could be drilled in the box and the capacitor could be zip tied if you prefer.
[ ] A Radio Shack (271-1341) 33K ohm bleeder resistor (used to discharges the filter capacitor at shutdown) is soldered in parallel with the filter capacitor terminals.

[ ] The two yellow wires from transformers T1 & 2 soldered to the AC terminals of the rectifier. Exercise caution in this operation, as the AC and DC connections to the rectifier MUST NOT contact each other during operation. It is a good idea to install heat shrink, on the yellow leads to avoid accidental contact, do not shrink in place at this time.

**Testing the rectifier output voltage**

[ ] Plug in the power cord and turn the AC switch on. Measure **across the filter capacitor terminals**. A reading of approximately 77VDC is normal.

[ ] Leave the power on for ten seconds, then turn the switch off and unplug the AC cord.

[ ] Feel the sides of the filter capacitor (do not touch the capacitor terminals) if hot, there is a problem. Most likely the polarity between the rectifier and capacitor is incorrect.

**Installing front panel components**

[ ] Install all the switches, make sure the switches turn “on” and “off” in the same direction, do ohms test to verify.

[ ] Install the remaining connectors, pot, jacks, etc. in their respective holes note instructions below for R5 pot.

[ ] Before mounting the potentiometer (R5), cut the shaft off, leaving approximately 3/8” remaining beyond the threads.

[ ] Place the potentiometer (R5) in its panel hole and rotate the potentiometer so that the three solder connection lugs face to the right, or toward the location of the control board.

[ ] Install the plastic LED (Light Emitting Diode) holder, but **do not** put the bicolor LED into the holder at this time.

**Installing control board and resistor bank.**

[ ] Secure the 10 mm stand-off insulators to the control board and mount the board in the generator box.

[ ] The power resistor bank (R1 & 2) is positioned over the ventilation holes and held in place with four 6-32 screws.

**Chapter 9**

**Final wiring and testing**

[ ] From transformer T3 select the two yellow wires, (if it is a 24VAC center tapped select a white and yellow wire). Strip the insulation back 1/4” on both wires, and secure one wire under terminal 7 and 8, on the control board Terminal Block strip (TB1-8).

[ ] Turn the AC switch on and conducted a test of the low voltage power supply circuit as outlined on page 48. Voltage readings are taken on both DIP sockets and the TB 1-8. The IC’s are not in the DIP sockets during the test. All readings are considered good if they measure + or - a few tenths of a volt. Make sure all voltages are present and correct before proceeding.
First voltage test of the control board

[ ] All readings are taken with the negative (black) side of the VOM connected to terminal 1 on the Terminal Block Strip. An alligator clip connected to this terminal and the VOM lead make life much simpler when doing these checks.

The following voltages are read on the LM-339 DIP

[ ] #3 pin 11.8VDC
[ ] #13 pin 11.8VDC
[ ] #14 pin 11.8VDC

The following voltages are read on the SN754410NE DIP

[ ] #1 pin 11.8VDC
[ ] #2 pin 11.8VDC
[ ] #7 pin 11.8VDC
[ ] #8 pin 17.5VDC
[ ] #16 pin 11.8VDC

If the tested voltages differ from those listed, a check of the circuit wiring is in order. Start with the output of the small rectifier mounted on the control board and see if a DC voltage is present. Make sure the filter capacitor is properly connected. If there is no DC voltage, check the input to the rectifier, it should be read approximately 13.5VAC

Wiring the rapid up down servo push switches

Refer to the schematic below when wiring this section, this schematic mates with the one on page 18.

The two push button switches (SW5&6) on the front panel provide a means for activating the rapid up and down movement of the ram.

[ ] A wire connects from one solder lug on the upper push button switch (SW5) to a lug on the lower switch (SW6). From this common lug, a jumper goes to the center lug on the potentiometer (R5), i.e. the three lugs are connected together. Do not solder the potentiometer connection.

[ ] The remaining lug on the top switch (SW5) has a jumper that connects to the topmost solder lug on the potentiometer (R5). Do not solder the potentiometer (R5) connection.

[ ] The remaining lug on the bottom switch (SW6) has a jumper that connects to the bottom-most solder lug on the potentiometer (R5). Do not solder the potentiometer connection at this time.

[ ] A wire from TB3 connects to the center solder lug on pot. (R5). Two wires connect to this lug; solder in place.
[ ] A 1K Radio Shack (271-1321) (R15) resistor goes in line between TB1 and the bottom solder lug on the potentiometer (R5). Two wires connect to this lug; solder in place.

[ ] A 1K Radio Shack (271-1321) (R16) resistor goes in line between TB2 and the top solder lug on the potentiometer (R5). Two wires connect to this lug; solder in place.

[ ] No connections are made to TB4.

**Wiring the servo jack and LED**

[ ] From TB5, a wire is routed to a lug on the servo on/off switch (SW4), solder in place.

Given the space available in the small enclosure, I decided to use a small 1/8” stereo jack for J1. This MUST be a Normally Open (N.O.) jack. The specified jack has five solder connections. Terminals 2 and 5 are the connections to use. If you are unclear which terminals on the jack to connect, conduct the following test.

[ ] Insert the plug into the jack, and remove the plug cover exposing three connectors, disregard the longest one. Conduct a continuity check (use a VOM) from the remaining two connections on the plug to find which jack terminals to use. Remove the plug and perform an ohm test between these two jack terminals, there should be infinite resistance between them i.e. (N.O.). Do a continuity check between the jack terminals and the enclosure there should be infinite resistance if it is not, the jack will not work for this application.

[ ] From the servo on/off (SW4) lug, a connection is made to lug 2 (or 5) on the servo jack (J1); do not solder at this time.

[ ] The remaining lug on the servo jack (J1), connects to TB6 on the board.

The bicolor LED (D3) wires in parallel with the jack (J1).

[ ] A 1K ohm Radio Shack (271-1321) resistor (R4) is connected in series with one of the LED leads.

[ ] Insert the LED (D3) in the plastic panel holder and solder the remaining lead of the resistor (R4) to one of the servo jack’s solder lug (J1).

[ ] The other LED (D3) lead solders to the other servo jack’s (J1) lug. There should be two connections each to servo jack (J1) terminals 2 and 5.

**Wiring the coarse /finish capacitor switches**

[ ] Solder an insulated wire to one of the lugs of the coarse capacitor switch (SW3), and route it to the TB14, which is closest to the photo flash capacitor marked with a (+) as shown in the photo on page 27. The remaining coarse capacitor switch (SW3) solder lug is not connected at this time.

[ ] Solder an insulated wire to one of the lugs of the finish capacitor switch (SW2), and run it to TB13, insert the wire and tighten.

[ ] Solder a jumper from the remaining lugs on the coarse (SW3) and finish capacitor switch (SW2), which ties them together.
The Banana Plug and TB9&10 connections

The red Banana (+) Plug (BP) has three connections, the connecting wires should be, 22 gauge or larger.

[] One of the wires to the red Banana Plug goes from the red Banana Plug to the output of the power resistor bank (screw connection on R1&2).

[] The next wire from the red Banana Plug connects to the common connector between the coarse and finish capacitor switches (SW2&3). The third connection is to be made shortly.

Two wires connect to the TB 9&10 I used two conductor stranded insulated wire i.e. lamp wire.

[] Cut a 6 1/2” length of the cord, separate the wire back about 1” and strip each end approximately 1/4”. Tin the copper wire with solder.

[] Insert one end of the cord into TB9&10. The polarity of this connector is indicated by an earlier marking. TB9 is marked positive (+) and TB 10 negative (-); verify the correct markings.

[] Of course, all connections are critical for successful operation, but the next four connections are particularly CRITICAL, if not correct, smoke!! I have learned that everything runs on smoke, it’s only when you let the smoke out that problems start 😊.

[] The wire from the positive (+) side TB9 connects to the red Banana Plug., solder in place.

[] The wire from the negative (-) side, TB10, connects to the black Banana Plug, solder in place.

[] Do a VOM continuity test to verify the connections.

[] From the cord, cut an 8” length, separate the wire about 1’, and strip each end approximately 1/4”. Tin the copper wire with solder.

[] One side of this cord solders to a diode rated for at least 3 amps. 200 PIV (Radio Shack 276-1144). The solder connection is made to the NON “banded end” of the diode, (insulate with shrink tubing).

[] The banded end of the rectifier solders to the negative terminal on the filter capacitor (C4), and power rectifier.

[] The opposite end of this particular wire solders to the black Banana Plug i.e. the diode is in series between the filter capacitor (-) and the black plug.

[] The second wire also has a 3 amp. diode (Radio Shack 276-1144) soldered in series with it (use shrink tubing to insulate). In this case, the NON “banded end” of the diode solders to the positive (+) side of the filter capacitor (C4) and power rectifier. The other end of the wire terminates at the input (screw connection on R1&2) of the parallel 20-ohm power resistors.

[] Use a VOM and do a continuity test to make sure the individual wires are going to the right locations.

Wiring is complete, if you are not using the optional meter

[] If a meters used, review chapter 7 for wiring details.
Turn the generator box upside down and shake it to remove any solder and wire clippings and other electrically conductive parts that may have dropped into the box.

**Control board and power supply voltage test**

Before conducting the next test, remove the I.C. chips from the DIP sockets if they have been installed.

Plug the generator in and turn on the AC power switch.

Switch the VOM to the AC range and read between TB7&8 on the control boards (left hand side); it should read approximately 13.5VAC.

With the VOM in the DC range, read the voltage across the Banana Plugs (red & black) it should be approximately 77VDC.

The next test is to take readings on the TB connector and both DIP sockets. **All test measurements are taken with the negative side of the VOM connected (use an alligator clip) to the negative (black) banana jack. All readings measured should be + or – a few tenths of a volt.**

The first voltage readings are taken on the TB connectors at terminals 2 & 3.

TB2 should read 11.8VDC

TB3 will vary from about 0 to 11.8VDC as the potentiometer shaft is rotated.

The following voltages are read on the LM-339 socket

- #3 pin 11.8VDC
- #8 pin 3.5VDC
- #9&10 will vary 0 to 11.8VDC depending on R5 position

The following voltages are not critical and may vary a couple of volt, as long as none of the voltages are higher than 11.5 VDC the EDM will work fine.

11 pin 8.3VDC assuming R11 is 6.8K ohm resistor
If R11 is 4.7K ohm resistor, the voltage should be 6.5VDC
If R11 is 10K pot. the voltage should be 8.6VDC

#13 pin 11.8VDC

#14 pin 11.8VDC

The following voltages are read on the servo drive DIP pins.

- #1 pin 11.8VDC
- #2 pin 11.8VDC
- #7 pin 11.8VDC
- #8 pin 17.5VDC
- #16 pin 11.8VDC

Turn the AC power switch off.
Voltage test of the LM-339 output’s

[ ] Inserted the LM-339 chip in the DIP socket with the “U” shaped notch on the chip facing the TB connector strip.

The following voltages should be read on the SERVOMOTOR DIP socket while rotating the potentiometer shaft 360 deg.

[ ] #2 pin, the voltage should snap from 0 to 11.8 VDC or vice versa

[ ] #7 pin, the voltage should snap from 0 to 11.8 VDC or vice versa

[ ] Turn the AC off.

[ ] Apply thermal heat sink compound and install a heat sink to the servomotor driver chip, it MUST have a heat sink.

Testing the output of the servomotor driver

[ ] Insert the SN754410NE servo driver I.C. in its socket. Make sure the “U” shaped notch on the chip’s end is facing the TB strip on the left hand side of the board.

[ ] Turn the AC power on, flip the servo switch (SW4) on. Slowly rotate the potentiometer (R5) knob. The LED (D3) switches from red to green (or vice versa). There should be a spot in between where the LED is turn off, adjust R5 to this null position.

[ ] Next, test the push button switches (SW5&6). One switch should cause the LED to glow green (servo down) the other push switch should cause the LED to glow red (servo up). Make a note which switch controls which LED color.

Making the generator power leads

[ ] The leads are made from a length of 18 gauge zip (lamp) cord, separate the wire about six inches on each end, and then strip the insulation from each wire back 1/4”. The ends solder into two Banana Plugs (Radio Shack 274-730). The opposite end of the cord has one each, 10 amp car battery charger clips (Radio Shack 270-343 and Radio Shack 270-344) attached. Make sure the red Banana Plug and the red 10-amp clip are on the same wire, repeat the same with the black Banana Plug and clip.

Simulate testing generator shorted condition

[ ] Plug the generator power leads into the Banana Plugs, keeping the ends separated. There’s 77 VDC present across the leads when the generator is turned on, so be careful.

[ ] Turn both capacitor switches (SW2&3) off.

[ ] Turn the servomotor switch on (SW4).

[ ] Turn the generator AC switch on (SW1).

[ ] Rotate the potentiometer (R5) to a position with no color showing on the LED (D3).

[ ] Short the generator clips together, expect a sharp “electrical crack”. The LED (D3) should turn red. Break the short; the LED should return to the previous state. This indicates the generator and control circuit are working correctly. Your LED colors may be reversed.
Setup and testing the servomotor

If the mechanical aspect of the servomotor is finished (page 74) an electrical connection for the motor to the power supply is made using a (3ft+) length of two-conductor stranded wire at least 22 gauge.

[] Solder the wires to the two short terminals (non-common) of the 1/8" stereo plug. The long strain relief crimp stops around the wire but no electrical connection is made. Thread the stereo plug cover in place.

[] Solder the other ends of the wires to the DC servo motor.

[] Solder a .1uf filter cap. across these motor wires i.e. parallel with the motor.

Optional, A Bi color LED and 1 K resistor (see schematic) in parallel with the motor gives a quick visual indicator, at the motor, of ram movement.

[] For the next tests make sure, the lead screw nut on the ram is mid position on the lead screw.

[] With the AC Power switched on, plug the motor connection into the jack (J1). Rotate the potentiometer (R5) to cause the LED (D3) to go out i.e. no ram movement.

[] Taking precautions as before, short the generator clips together. The LED (D3) should turn red and the ram should retract. If the ram did not retract, reverse the wires that connect to the DC motor. If this is not done the EDM will not work proper and the servomotor driver chip may be destroyed when in an EDM operation. Be careful not to retract the slide too far toward the motor, this particular head design does not have limit switches, the motor will stall and may destroy the servo drive chip.

Cooling fan hookup

The last item to wire is the 3" cooling fan (M1). Make sure the generator is disconnected from the 120VAC line.

[] Two cooling fan wires pass through the box cover, these wires connected to the junction where the three black transformer primary wires connect to each side of the 120VAC line. Slide the shrink tubing from around the two connections and solder the cooling fan wires in place (five wires total). Once soldered, let the joint cool; slide the shrink tubing in place and shrink around the connections.

Finishing touches

[] The only thing that remains is labeling the controls. The new generation of label makers such as DYMO (and others) are excellent for making professional looking control labels. The generator is now officially finished!!! Read chapters 14&15 before proceeding with your first burn.
Chapter 10

EDM servo head overview and options

The Servo head consist of a DC gearmotor which rotates a leadscrew driving a slide, or ram (in EDM lingo used interchangeably), up and down. The DIY slide outlined in the text is similar to the low friction ball slides used in most commercial EDM machines. Attached to the moving slide/ram, is a block called the platen; the platen is electrically isolated from the metal slide. Electrodes are attach to the platen via clamps, chucks, etc.

Servo head option

There are two options suggested in this book for the servo head. One is to purchase an off-the-shelf aircraft trim servo. Modify it slightly, and wala, you are in business. The other option is to build a head as outlined in the text.

The advantage of the first option is:
1. It is almost a plug and play servo, which permits getting an EDM machine operational quickly.
2. If you do not have minimal shop tools or skills to build a servo head, then it may be your best choice.
3. It is small and light (4 oz.) enough to mount on a dial indicator magnetic base for doing EDM work in remote locations.

The disadvantage is:
1. It is an expensive item (in my opinion, but then again, I am known as a tight wad).

2. The servo ram travel is limited, but even with the small travel; a lot of EDM work may be done. This is especially true if the head is mounted to an existing milling machine or drill press quill which will permit large travel movements.
3. The ram itself is rather small, which will decrease its rigidity, and makes it more of a challenge to attach electrodes to it.

The aircraft trim servo may be purchased direct from the manufacturer, the Ray Allen Company, (see Appendix). There are two versions that I have used successfully:
T2-10A has 1” travel
T2-12A has 1.2” travel
The T2-12A I have is shown below

The square ram extends from the bottom; the rising stem (stationary) lead screw extends from the top. A rotating nut driven by a small D.C. motor inside the servo, causes the ram to rise or fall depending on the electrical polarity applied to the DC motor. The T2-10A does not have a lead screw protruding through the top of the servo case.

On the version of the T2-12A, that I have, which is several years old now, the ram is machined flat on the end with a hole drilled and threaded through the ram’s center.
Evidently, the present version (on the website) shows the ram with a hole drilled at a right angle through the ram. If this is the case, the electrode-holding device will need to be mounted differently than what I show.

**Fabrication of a mount for the T2-10A & 12A servo**

I had a piece of aluminum extrusion in the scrap box that the “L” shaped 1 1/2” x 3” x 1/8” mount was cut from, see photo below left.

[ ] Any piece of rectangular tubing or angle iron of the needed size will work, or you may bend a piece of sheet metal to achieve a 90 deg angle. The four mounting screw holes are on a 2 3/8” square.

![Mounting Mount](image)

[ ] I placed the centerline of the ram on the centerline of the drill press/milling machine spindle. To do this, the 1/2” mounting post is positioned 1 1/16” from the right side and centered over the lead screw. If the T2-12A servo is used, the mounting post must have a clearance hole for the rising stem, see above photo. The photo on the right above shows the complete EDM ram located on the centerline of the machine tool.

A simple electrode-holding device for beginning EDM experiments is a 3/8” drill chuck. It works well for cuts where a single electrode is all that is required. Should you get involved in more advanced EDM work, this holding method will not be satisfactory. It does not permit the electrode to be removed from the holder, and then replaced in the exact same position. The shortcomings of this type of holder will become more evident as you read the latter sections of the book on Indexing electrodes.

[ ] Most small drill chucks I am familiar with are mounted with a 3/8-24 thread. The chuck is attached to the ram via a 3/4” length of 3/8-24 thread rod. (A 3/8-24 bolt maybe purchased and a 3/4” length of the threaded section cut off.)

[ ] Drill a 3/16” hole completely through the center of this threaded rod. Through this clearance hole, a 1” long 10-32 screw is inserted and threaded into the end of the plastic ram securing the 3/8-24 threaded rod to the ram.

[ ] The chuck is threaded in place, see photo page 62 right.

**Chapter 11**

**The shop built servo head**

I have developed a very low cost, easy to fabricate, servo head using a modified “drawer slide”. The accuracy is excellent, if care is given to details during construction. I have been impressed with the precision, which maybe achieved given the time, cost, and technical skill required to fabricate the servo ram. The servo head as described has a maximum travel of 2 5/16”. It is possible to get even more travel by extending the lengths of the slide and lead screw.
The advantages of this shop built head are:
1. Very low cost.
2. Ram travel can be customized to your application.
3. The rams construction is very rigid.
4. It’s possible to have a large platen to attach the electrode holder to.

The disadvantages are:
1. It will require time to build the head.
2. Some shop tool and basic skills are required.
3. The lead screw requires precision lathe work.

**Servo gearmotor selection**

Most of the plans for building EDM machines I have seen use **stepper motors**!! Why anyone would do this is beyond my understanding!! It greatly increases the complexity of the design and I see no advantage in most cases. I use a small, very simple, and rugged gear reduction D.C. motor. The photo below is of a Pittman gearmotor purchased via surplus supplier, (see Appendix). There are many manufacturers of these small gearmotors. Names you will see: Barber-Colman, Von Weise, Merkle, Korff, Molon.

![Servo gearmotor](image)

Basically, you want to make sure that it is a DC gearhead motor and operates on 12VDC (no more than 24VDC) the output rpm of the gearbox on my motor is 80rpm’s. If the selected motor output is 20 rpm above or below this, at the designed working voltage, it will still work fine in this application. These motors may be found in many electronic surplus houses, prices of most motors $15-$25 (2005).

**DIY servo construction**

The ram’s slide is based on a “center under mount drawer slide,” purchased from a Lowe’s home center store. It is a Knape & Vogt KV1129PZC16 rated for 35 pounds. I do not think it is important to purchase this particular slide, but the slide must be the ball type. Some slides appear to be built to closer tolerances than others. If possible, before purchasing, extend the slide to its maximum length to check for rigidity. If there is play, reject it, and select another one.

These slides have four parts. I have assigned names to the following items:
1. Outside traveling slide,
2. Inside stationary slide,
3. Ball bearings,
4. Ball retainer cage.

The purchased drawer slide has 12 steel bearings, but only four are needed to build a good compact EDM ram. The photo on page 66 (left) shows all the parts required to build the head. The photo on the right shows the assembled head.

[ ] Completely disassemble the slide and cut the following lengths from the slide.
5 1/2” length of the smaller width inside slide.
4 1/2” length of the wider width outside slide.
[ ] The ball retainer cage is cut so that there will be a minimum of four balls spaced at least 1 1/8” apart.

[ ] About 1/8” from the end of the wide traveling slide, cut (hacksaw) a slot as seen in the photo (left) below repeat this for the opposite end of the same slide.

[ ] Using a file and sand cloth, remove all burrs, paying particular attention to the area of the cut slots.

---

**Lead screw nut**

Suitable material for the lead screw nut is a 1” length of 1/2” square steel key stock. The preferred material is brass or a plastic such as Delrin, see photo above, right.

From the end, move over 5/8”, drill and tap a 3/8-24 hole through the center of the stock. The correct drill for this operation is a “Q” drill, lacking that a 21/64” drill will work, assuming you have a sharp tap. Other thread pitches will work, though I have not experimented with pitches coarser than 20 t.p.i. (threads per inch).

Rotate the stock 90 deg., 5/16” from the end on the center line, drill and tap a 10-32 hole through the material.

**The lead screw**

It’s critical that the 3/8-24 (or whatever thread pitch is selected) lead screw be fabricated accurately to get the smoothest operation. In most cases, this means using a lathe. If possible, the lead screw should be held in a collet during the machining process, to ensure the most precision. Should you not have the skills or facilities, consider having the work done by a high school or technical school shop class. Note If you are unable to get the work done I am willing to manufacture the needed screw for a reasonable fee, see my address/email in the front of the book.

[ ] The diameter and length of the gearmotor output shaft needs to be known, for this operation. Cut a length of 3/8” cold roll steel 4 3/4” long. Drill and ream a sliding fit hole in one end of the stock to accommodate the length of the motor output shaft, the motor I used has a 3/16” shaft 3/4” long.
I suggest two methods of attaching the lead screw to the motor output shaft.

**Method #1 setscrew/pin**

The most common method is to use a setscrew to lock the shaft to the motor. The problem is that it tends to pull the lead screw slightly off the centerline, in most cases causing binding of the lead screw.

[ ] If you choose this method drilled and tapped a #4-40 hole at right angles to the previously reamed hole.

An alternate version, which I prefer, is to drill a 1/16” hole through the lead screw and motor shaft then insert a 1/16” pin through the two. This eliminates the binding problem but is more difficult to machine accurately.

**Method #2 glue**

Torsion loads on the lead screw are not great, which means a two-part epoxy maybe successfully used. The disadvantage, if parts need to be disassembled, it’s a pain. The advantage of using glue as the connecting agent, is it virtually eliminates the binding problems associated with the setscrew and the complexity of machining with the pin method.

[ ] Single point threads, on a lathe, for a distance of 3 3/4”. Use the previous made lead screw nut to test the fit. Get the least backlash possible without binding, no sloppy fit here!

[ ] Once completed, cut the lead screw to a length of 2 3/4”. The remaining 1” threaded piece is squared on the ends (use the lathe to square it). This will be used later to mount the electrode holder to the platen.

Whatever the attachment method it’s necessary to remove the motor output shaft endplay. This is accomplished by installing a nylon washer (to act as a bearing) and a wavy washer between the motor housing and lead screw, see photo above. The wavy and nylon washer are in the specialty fastener section of most hardware stores. They may be purchased from either of the following companies.

http://www.smallparts.com
http://www.pic-design.com/

[ ] If attachment method # 1 is used, place the lead screw on the motor shaft, partially squeezing the wavy washer (i.e. preloading the shaft), then tighten the setscrew against the shaft, hopefully the shaft has a flat on it, if not file a flat.

If attachment method #2 is used the following steps are necessary.

[ ] Make sure all surfaces are cleaned with acetone or another similar degreaser.

[ ] Place the nylon and wavy washer on the shaft.

[ ] Put a two part epoxy glue, such as JB weld, in the lead screw hole and cover the motor shaft with glue as well.
[ ] Place the motor and lead screw assembly between the jaws of a vice (or “C” clamp) and squeeze until the wavy washer is partially collapsed.

[ ] Leave the motor in the clamping device and let the glue fully cured, usually 12 hours, read the glue instructions.

**The platen**

The platen (the white plastic block in the photo page 71) electrically isolates the electrode from the ram. A small piece of plastic was found in the scrap box (delrin preferred) to use as the platen.

[ ] I machined a piece 3/4” square x 1 1/4” long plastic. Then drilled and tap a hole for 3/8-24 threads in one end (1/2” deep).

[ ] Measure 1/2” from the opposite end and drill a 3/16” clearance hole thru for a #10-32 screw.

**Mounting arm**

The mounting arm is made from 3/4” or 1” square steel tubing 3 1/2” to 5 1/2” long, dimensions not critical.

[ ] Move 5/8” from one end, and drill a 3/8” thru hole. At 90 deg. to this hole, on the opposite end, drill two 1/8” holes spaced 7/16 apart. See middle drawing on page 70.

[ ] The mounting post is made from a 3” long 3/8” bolt with the head removed, see drawing, page 70, debur and assemble.

**Final slide preparation**

[ ] The wider of the two slides is the traveling (moving) slide. Mark and drill a 3/16” hole 1/4” from one end of the slide (this hole is off set 1/4” from the centerline). The lead screw nut attaches at this location.

[ ] Measure from the other end of the slide 3/4”, on the center line, drill a 3/16” hole. Through this hole the plastic insulating platen block attaches with a #10-32 screw, see photo below.
A second screw may be added for rigidity. This would involve drilling an extra hole in the slide and plastic platen.

[ ] Layout and drill the stationary slide as per the drawing below.

[ ] Using a square, position the mounting arm and the slide 90 deg. to each other and secure with two screws see drawing below and on page 73.

**Slide assembly**

[ ] Slide assembly can be a little tricky. First, remove all dirt and metal chips from the bearings and bearing surfaces.

[ ] Start by holding two balls in the ball retainer cage, and insert them into the traveling slide on the mounting post end of the inside stationary slide.

[ ] Push the traveling slide forward until it is time to install the last two balls.

[ ] With the balls in position, slide the traveling slide further into the stationary slide. The drawing on page 72 shows the slide in a semi-extended position.

[ ] When the slides are assembled and lubed with a light oil or grease, the movement should be silky smooth; if not clean and reassemble.

[ ] Once the two slide are in position and smooth movement is noted, squeeze the two 1/8" metal tangs cut on the traveling slide slightly closed. This will keep the balls and ball retainer captive in the moveable slide.

[ ] Double check the slide and mounting are square (see drawing above). Tack welding the two will guarantee no movement.

**Electrode holder**

As previously stated a simple electrode holding device is a 3/8" drill chuck. It works well for cuts where a single electrode is all that is required. It does not permit the electrode to be removed from the holder and then replaced in the exact same position.

Most hardware stores sell replacement chucks for a hand drill. Experience indicates most of these chucks use a 3/8-24 threaded stud to attach them to the drill.
The 1" length of material cut from the lead screw is used to attach the drill chuck to the plastic electrical isolation block. Thread the stud into the back of the drill chuck and also into the drilled and taped platen.

**Gearmotor mounting**

Thread the lead screw nut up the lead screw to within 1/4" of the gearmotor housing. On most gearmotors, the output shaft is off the motor centerline. This permits a very simple self-centering method of aligning the motor and the lead screw nut.

To accomplish alignment, rotate the motor housing until the outside of the gearbox lays squarely (near the top) in the groove of the small stationary slide; see (left) photo page 75.

Install and tighten a hose clamp around slide and motor.

Connect the motor to the EDM generator, if it is finished, see page 58 for details on wiring the motor. If not finished connect to a 12 volt battery or other 12VDC source.

Run the slide back and forth (reverse polarity) and adjust the position of the motor, until no binding is evident.

**Note:** To keep things simple I have not incorporated limit switches Therefore it is possible to run the slide into the gearmotor housing and stall the motor. Stalling the motor has the potential of destroying the generator motor driving chip so be careful. The servo is now complete, see the photos on page 75 the finished head is shown (right) with an aluminum cover over the slide to dress it up a little.

---

**Chapter 12**

**Dielectric tank overview and construction**

A well designed dielectric tank and filter system do several things:

1. It contains the dielectric fluid around the workpiece.
2. Provides a method to accurately secure the workpiece.
3. Circulates clean filtered dielectric fluid to the gap.
4. Electrically isolates the electrical discharge from other parts of the machine.
5. Provides a rapid method for filling/draining and storing the dielectric fluid.
For serious EDM work, a tank needs to have a pump, filters, and a work holding plate. The photos and descriptions in this section are of a (rather large) tank that has proven to be of a very versatile design. After 10 years of use in portable, as well as stationary applications, there are few, if any, changes that I would make to the design.

I cannot over stress the importance of have a good dielectric filtering and flushing system for your EDM. A good flushing system will make a poor EDM generator look good, a poor flushing system will make a good EDM generator look bad. **The dissatisfaction with many home built EDM machines I think comes from a poorly designed, or nonexistent, dielectric cleaning and flushing system.**

Use ideas presented here and build a good dielectric tank to suite your particular needs. Before getting into details of how it is built, I would like to suggest a possible alternative.

**Building the dielectric tank**

The photo on page 77 shows an overview of the EDM tank in my shop. In the center of the photo, notice a black electrode mounted in a square ram, disregard this particular ram. This particular tank is part of a self-contained stationary EDM in my shop. The focus in this section is building the dielectric tank only, not the ram.

The tank shown, holds 5+ gallons of dielectric fluid and is large enough to accommodate most of the EDM work I do, and most likely the work you will be doing. The dielectric fluid, when not used, is stored in a 6 gallon plastic tank (not shown) under the workbench. The dielectric is quickly transferred from storage to the work tank by applying low-pressure (1-3 psi.) compressed air to the sealed storage tank, forcing fluid into the work tank. Once filled, a simple valve inside the work tank is closed containing the fluid. To empty, the valve is opened and the fluid drains by gravity back to the storage tank.

If compressed air is not available, another option for automated storage is to use the circulating pump in the work tank to pump the dielectric to a storage container above the work tank. When the work tank needs filling, a valve is opened and the work tank is filled by gravity. Using the pump method, the transfer of dielectric fluid is much slower than using compressed air. But this method does not require any holes to be cut in the work tank.

**Tank selection**

To accomplish precision EDM work, it is necessary to accurately hold the workpiece in the tank via clamps, vice, etc. This necessitates a metal plate be attached to the tank bottom. I prefer to glue the plate in place and not penetrate the work tank boundary anymore than necessary.

The glue method rules out the use of polyethylene containers, as there are no common glues that adhere to this very slick flexible plastic commonly found in kitchenware.
The tank material of choice is fiberglass, which glues adhere to very well. The fiberglass containers that I recommend are intended to be used for commercial storage and transport of parts. They are manufactured by Molded Fiber Glass Tray Co.

The product is called Toteline, and they come in various sizes and colors. Several industrial suppliers sell these containers. (see Appendix). The tank shown in the photos in this section is a Toteline model 814-308. The outside dimensions are 25 3/4" x 15 3/4" x 7 5/16". If this tank is too large for your application, their website lists several smaller size tanks. I recommend staying with the 814 series of tanks, which have four flat walls, making it easy to mount the filtering system.

Using the Toteline model # 814-308 permits a respectable 12" x 15" work plate; a two-filter filtering system, along with associated plumbing; and a dielectric pump; all of which may be housed inside the tank. Using this in-tank design, filters are changed without spills dielectric fluid outside the tank, which is really a nice feature. For a portable EDM system, having virtually everything contained inside the tank has some real advantages during use, as well as storage. Given these advantages, this system is not for everybody; some have space concerns and elect to use a smaller tank and/or position the filter/s and pump external to the tank; it's up to you.

Tank fill and drain

The dielectric tank described, has only one holes drilled through the tank below the dielectric fluid line. A thru-hull connector, and a bilge hose from the pleasure boat market, make it possible to fill and drain the tank thru this one hole. The thru-hull connector is available in straight and 90° configurations. The larger diameter thru-hull connectors are usually referred to as cockpit drains, see following photos. They are better in most cases, as it will speed the filling and emptying of the work tank.

The connector and matching bilge hose are available at most boat and marine supply houses. If there is not a local source for these parts, check the Attwood Marine web site (see Appendix) and look under pump accessories for the needed items.

Drill a hole in the bottom or side of the tank (hole saws work great) to accept the size connector purchased. I placed the drain in the bottom of the tank (see photo below and on page 80) to ensure the complete draining of the tank. Even with a bottom drain about 1/4" dielectric stands in the tank when empty. If a portable EDM system is built, a hole in the side of the tank may be the best choice. The disadvantage of using a bottom drain location is that it may pose a problem when mounting the tank on a flat surface, such as a milling or workshop table.
If you are duplicating the described tank, the hole location is in the tank bottom, front left hand corner. Measure inside the tank 1 1/2" from left wall, 4 1/2" from front wall. Knowing the precise location is important when installing the fill valve.

The photo below shows the top side of the thru-hull drain. Notice the tapered angle of the opening in the drain thru-hull connector. This was not cut by me, but is the way this particular connector was made. This angle works great in conjunction with the valve to form a good seal. Even if the thru-hull connector purchased does not have the angle, as long as the opening is smooth, it should provide a seal to keep the dielectric from draining back into the storage tank.

![Thru-hull connector](image)

**Work plate selection and mounting**

Decide on the size work plate you want. I chose a 12" x 15" x 3/8" aluminum plate (steel is also acceptable).

I recommend drilling and tap a series of 1/2-13 holes (on 2 1/2" centers) in the work plate. These holes provide a means of holding common fixture/hold down devices.

Debur all holes and edges, particularly on the surface of the plate that will contact the tank’s bottom. When glued in place, the plate must be as parallel to the tank bottom as possible in order to accomplish accurate EDM work.

Mark exactly where the plate is to be positioned in the tank.

Rough up the bottom of the tank and the work plate with coarse sandpaper.

Removed all traces of dust, use a solvent such as acetone to remove any oil from the tank and plate.

A glue that is known to work well for attaching the work plate is a 5 minute epoxy Plastic Welder #14300 made by the Devcon Corporation (see Appendix). This glue is used because it has very good resistance to the hydrocarbons found in the dielectric fluid. No matter what glue is used, make sure it is resistant to solvents.

Place the fiberglass tank on a flat surface, very important!

Apply a uniform bead of glue on the backside of the work plate, leaving a glue free space around each threaded hole in the plate. This will minimize the amount of glue that “squishes” into the holes when the plate is set in the tank.

With a wooden paddle, mix both parts of the glue together. I suggest doing the mixing right on the work plate. This is a time when two people are better than one; the glue has only a 2-3 minute working life.

Position the plate in the work tank with weight on it, the more the better to keep plate and tank parallel. Use a “Q” tip
to remove any glue in the threaded holes. Full bond strength of this particular glue occurs in 8 hours. I have used this glue on quite a few tanks and have never had a problem with the work plate releasing from the tank, even when left for extended periods with dielectric in the tank.

**Dielectric pump and filters overview**

If the EDM operations last for more than a few minutes, it is necessary to supply a clean flow of dielectric fluid to the gap area. This will promote an efficient stable burn under most conditions. A brushless 120VAC submergible pump is used to circulate fluid through a set of automotive (spin on) oil filters for cleaning the fluid.

The submergible pump must contain Viton seals to stand up to the EDM dielectric. Various industrial suppliers such as Grainger, Beckett, and Teel sell suitable pumps (see Appendix). I used a Grainger model #2P407 though it appears as of this printing that Grainger may be no longer carrying this particular pump, BTW Grainger does not sell direct to the public.

The Beckett model is G600AVS. By typing Beckett G600AVS into a search engine you can come up with several on line sources for the Beckett pump. This pump is rather expensive but it is a good choice for the application, because it flows a respectable volume of fluid at a relatively high head pressure for a small pump. I have had this pump in operation for about 10 years with no problem. There are some solvent tank pumps that are less expensive, but in most cases develop a lot less head pressure.

**Filter mounts and filters**

Remote oil filter mounts are used in the automotive industry. Dual and single oil filter mounts are available, see photos.

These remote oil filters mounts may be purchased from Jgs High Performance. [http://www.jegs.com](http://www.jegs.com) (see Appendix)
They are also available from [http://www.holleyreman.com](http://www.holleyreman.com)

[ ] Purchase spin-on oil filters to fit your particular mount.

**Filter mounting and plumbing**

To mount the two-filter system, a spacer block, (as shown on page 84 bottom photo) 5 1/2 x 2 x 3/4" is need. The block may be made of metal, plastic, or wood. This block will correctly position the filter mount above the drain/fill hole.

[ ] Next, locate the centerline of the thru-hull connector drain hole. On this centerline, a 1/2" hole is drilled through the
filter mount. This hole should fall close to the location seen in the photo below.

Drill holes in the tank and spacer block to match the filter. Mount the spacer block, and filters, see photo page 88.

The drain valve

The drain valve consist of a ping-pong ball, a 9 1/2” length of 1/4-20 threaded rod, four 1/4-20 nuts, one 5/16-18 nut, and a 2” length of 1/2 diameter aluminum rod with a thru hole (optional).

Note: In the photo on page 85, there is a short bolt glued to the right hand side of the ping-pong ball; disregard, as that was part of a design that did not work out well, but was never removed. The parts of the drain valve are glued together using the same glue as used for the work plate.

[] On the top of the ping-pong ball, glue the 5/16-18 nut. Do not let glue “squish” into the threaded area of the nut. Permit the glue to reach full cure strength.

[] Thread two 1/4-20 nuts on one end of the threaded rod, leaving 1/4” of the rod extended through the bottom nut. Run one nut against the other in jam nut fashion.

[] Mix a small amount of glue and fill the hole of the 5/16” nut, then insert the short end of the threaded rod into the nut and rotate the rod. This causes the glue to attach to the thread rod and to squeeze between the two nuts for a strong bond.

[] The 1/2” aluminum sleeve on the threaded rod gives a smooth slip fit through the filter mount base, see photo.

In operation, compressed air (approximately 3#) is applied to the storage tank, forcing dielectric fluid past the ping-pong ball valve. When the work tank is full, the air pressure is cut off. As the dielectric starts to flow back to the storage tank, it pulls the ping-pong ball against the thru-hull connector thus closing the valve. To drain the tank, lift the ping-pong ball valve stem.
Final tank plumbing

[] To finish the tank plumbing, purchase the following 3/4” PVC items from a hardware store. Two 90° elbows, three male and one female threaded couplers (to match the oil filter mounts and pump, usually 3/4” NPT), as well as an end cap, and enough (approximately 3 feet) 3/4” schedule 40 PVC pipe to plumb the system (see Appendix).

If a portable system is being built, or if the storage tank for the dielectric fluid will be higher than the work tank, a valving system is needed to control the flow of the dielectric fluid to and from an elevated storage tank. The valving is a good idea, even if a portable tank is not being built. The valving consist of an adapter to go from a 3/4” NPT (pipe thread) to a garden hose thread, as well as a garden hose “Y” and straight shut off valve; see photo below. Also, purchase a male brass 1/2” garden hose replacement end (remove the steel crimp teeth), a 3” length of 1/2” copper tubing, and a 45 deg elbow to match.

[] To one side of the elbow, solder the tubing. To the other side of the elbow, solder the brass replacement end, as shown. By opening and closing the appropriate valves, it is possible to permit the fluid in the tank to be circulated for filtering, or be discharged to a storage tank higher than the work tank.

Dielectric cleaning tips

Filter life may be extended by placing bar magnets at random locations in the dielectric tank. Metal swarf particles floating in the dielectric are attracted to the magnets. To clean remove the magnets and wipe the residue off with a cloth. Letting the swarf settle out in the storage tank after a burn extends filter life also. If the EDM is used often it is a good idea every week or so to remove all dielectric from the storage tank and properly dispose of the settled swarf. If not removed, over a period of time it tends to pack in the storage container and is almost impossible to remove.

Static discharge dissipater and AC switch

[] Drill a 1/16” hole through the center of a brass plug that threads in the discharge side of the oil filter mount.

[] Solder an 18 gauge copper wire in the hole, see (left) photo page 88, which is long enough to extend the full length of the PVC plumbing. This wire discharges most of the static charge (to ground), which is naturally developed as the dielectric is pumped through the fiberglass tank and plastic tubing.

[] The on/off switch for the motor is a standard 120VAC household light switch installed in a metal switchbox; no plastic boxes, see (right) photo page 88.

[] Drill and tap 10-32 holes between the inlet and outlet tubing on the filter mount. Using long 10-32 screws, attach the switchbox to the oil filter mount. The switch box needs good physical/electrical contact with the filter mounts. The static discharge passes through this connection.
When wiring the switch, use a three conductor AC power cord (Radio Shack #61-2859) or similar. Strip the covering back about five inches, exposing the three inner wires.

Strip the black and white (some are blue and brown) wire ends back 1/2" exposing the bare wire. Strip the green wire back 1".

Thread the cord through the switch box and clamp the strain relief snugly against the AC cord.

The switch and motor are wired in series, secure the connections inside the switch box with wire nuts (Radio Shack 64-3057)

This is very important the green wire from the plug and the ground wire from the motor must have good electrical contact with the oil filter mount. The static charges collected by the wire are discharged to ground through these connections.

Flexible flushing line

To direct the clean dielectric fluid to the area of the gap, use a product called Loc-Line, see photos below. A similar product by other manufacturers is called Snap Flow, Snap-Loc etc. These products are available with various valves, nozzles, connectors, etc., (see Appendix)

Purchase at least one male 1/8" NPT valve, a round 1/8" nozzle, and a foot of the Loc-Line. Many industrial suppliers sell a kit with these basic items for less than $10 (2005). Should your flushing methods include through electrode flushing, pot flushing, etc. (see the EDM techniques and methods section), purchase at least two of each item listed.

In the filter (PVC) discharge line (which runs from the filter make a 90 deg. turn and then follows along the back side of the tank) drill and tap a 1/8" NPT hole for the Loc-Line male valves to thread into. In the right hand photo above, note the placement of a PVC coupling. By cutting the line and inserting this coupling, it provides a little more thickness of PVC material to thread the flush line fitting into. Install as many flush lines and valves as needed on this PVC discharge line.
Along the backside of the tank, drill several 3/32" holes. Through these holes, zip ties or wire are used to hold the PVC pipe in place, see photo below.

![Image](image1.png)

**Portable applications**

The dielectric work tank may be set up temporarily on a milling or drill press table. For such an application, the tank should be attached to the table securely. This is accomplished by adding two "feet" to the tank. These feet are glued to the tanks ends, see photo below.

![Image](image2.png)

The feet are 11" long (or as dictated by your tank size) and cut from a piece of 2" angle iron. Center the feet on the tank ends and mark the location.

![Image](image3.png)

Sand the tank to rough the surface so the glue will adhere in the contact area. With acetone, or similar solvent, degrease the angle iron and tank.

Position the tank on the milling/drill press table. Clamp one angle iron piece in place. Use the same glue used to glue the plate in the tank bottom. Apply this glue to the angle iron. Slide the tank against the angle iron.

Repeat the same process on the other end of the tank and let the glue fully cure.

**Stationary applications**

Building a stationary EDM machine is really beyond the scope of this book but, if you are building such a machine the tank may be placed on a drill press table, or you could build a column with an over reach arm that the servo ram is attached to. Either way, a low cost "X" "Y" table (also called mill and drill table, or some times called compound slide milling drill table) as seen in the photo below, will serve well for moving the tank in the "X" "Y" axis. Depending on size and travel, these tables cost between $75 and $200 (2005); most industrial suppliers carry them.

In my application, I cut, from a piece of particle board, a section large enough to fit under the dielectric tank (particle board is very precise in thickness) It is a good idea to water proof the board or put some kind of sealer on it to minimize moisture absorption by the wood. Secure the board to the "X" "Y" table with "T" nuts and flat counter sunk screws. The tank maybe glued directly to the particleboard.
If you choose this method, it will be almost impossible to remove it from the table without destroying the setup.

If you have feet on the tank (as described in the previous section), holes maybe drilled through the feet and screws or bolts used to hold the tank in place on the particleboard. The dielectric tank is now complete, except for the storage tank.

Chapter 13

Storage tank options and construction

The simplest storage system is one where the dielectric is kept in a covered container, such as a five-gallon bucket. The work tank would have a flexible drain tube on the bottom or side of the tank. The end of the drain tube attaches to the tank side, above the dielectric level in the tank. Dielectric is manually poured from the storage container into the work tank. When the EDM job is finished, or when the dielectric level needs to be lowered to facilitate working in the tank, simply drain the tank into the storage container. It’s a bit messy, but is low cost and works well.

Storage above the work tank

Having the storage above the work tank may be used for both portable and stationary applications. This storage method requires a stand on which to place the tank. A covered, and vented, five-gallon plastic bucket works well for storage. Cut a hole in the bottom, or through the side, and place a through-hull connector in it; see page 79. In this case a 3/4” size bilge drain hose will work well with the garden hose “Y” valve used on the work tank; see page 86.

By turning the pump on and opening and closing the correct garden hose “Y” valve, it is possible to direct the dielectric flow into the storage tank, or vice versa. One of the real advantages of this method, is that it does not require holes in the work tank below the operating level of the dielectric. This is a very clean storage method. The disadvantage is that the filling and draining of the system is much slow than using the previously described pour method, or the airlift method described in the next section.

Storage below the work tank

For those that wish to have the most advanced work tank filling and storage system, the following will serve you well. I used this method on my stationary EDM. It is very similar to the systems used on many commercial EDM machines. This method can be used, even in portable applications where air pressure is available. All that is needed, is a sealed tank an air regulator, and a three-way valve, to admit and vent the tank.

For the most part, the storage tank is simple, yet it poses some difficult problems. Assuming the previously described work tank is being used, a minimum of five gallons of storage is needed (six or more is preferable). The storage tank must be completely sealed and capable of withstanding at least three to five pounds of pressure. Most of the plastic kerosene and water storage containers, as well as some plastic gas cans, meet these specifications.

The tank must have two openings, one through which air pressure is applied, and a larger hole to discharge the dielectric through. I have noticed recently, that many of the plastic gas cans no longer have a separate vent in them; instead they are vented via the pour spout. This new type of venting system creates a problem in our application, as there is no readily accessible vent hole to apply air pressure (above the dielectric) through. Use your creative juices here to overcome this problem.
The tank seen in the photo below, (left) had a vent hole with a thread-on cap to seal it. I removed the vent cap and connected the inlet airline using a hose clamp to seal it. How the inlet air pressure is applied to the storage will be determined by the design of the storage tank selected.

Some kind of valve is need to turn the air pressure on and off to the storage tank and permit the air to escape when refilling the tank. I had a difficult time locating a reasonably priced, three-way air valve, so a three-way fuel valve was used. These valves are readily available via most auto parts stores. They are used to switch from one fuel tank to another, on a vehicle. The one I have been using, has worked well for this purpose for the last 10 years; see the photo above on the right.

Since you will be purchasing a tank from a local source that may vary in design from mine, it is difficult to give hard info as how best to seal your tank. No matter what kind or style of the tank, there are three basic rules to follow:

1. The tank must be sealed.
2. The discharge pipe must extend from the opening of the storage tank to the bottom.
3. There must be a means of applying air pressure above the top of the dielectric.

The description that follows, pertains to how I sealed the particular tank chosen. The discharge pipe passes through the tank pour spout hole, and the (threaded) tank cap. In most cases, it will be necessary to enlarged both to accept the 1” schedule 40 PVC discharge pipe. This pipe is about two feet long for a 6 gallon tank. The tricky part is getting a good seal, where the PVC pipe passes through the storage container opening. Having access to a machine shop, of course, made the job a simple affair.

[ ] Enlarge the pour spout and cap, to accept the discharge pipe.

[ ] Slide the pipe through the snug tank opening all the way to the bottom on the opposite side of the storage tank.

[ ] Using a marking pen, draw a circle around the pipe where it comes through the tank.

[ ] Machine a standard 1” PVC coupling to have a very snug fit over the pipe.

[ ] From the machined coupling, cut a 3/16” wide (or wider) ring; see (left) photo on page 96.

[ ] The ring is placed over the PVC pipe and glued in place by the previous pen marking. Use regular PVC glue to join the pipe and ring.

[ ] At a hardware store, I found a rubber gasket, used to seal sink drains, that was large enough to slide over the 1” PVC.

[ ] The complete assembly with rubber gasket between the tank, and the PVC lip pipe is shown on page 96, right photo.
The existing tank cap was then placed over the pipe and threaded tight. This seals the discharge side of the tank.

It is not necessary to make and glue the PVC ring to the pipe, though in my opinion, it is best to ensure a good seal. I have, on some tanks, used just an “O” ring around the pipe and placed the cap over the tube, and tightened in place. Other materials that may be used for sealing are pump packing, cutting rubber gaskets from inter tubes, etc. The bottom line is that the tank needs to be as airtight as possible.

I used bilge pump line and stainless steel automotive type clamps to make the drain/fill connection (left hand side of photo above) to the through-hull connector on the work tank and the storage tank.

Chapter 14

EDM techniques and methods

The following section, as far as I know, is unique to all EDM plans I have seen. Most plans for EDM machines tell you how to build a very complicated machine, and never give any real hands on application information. What good is an EDM machine if you really don’t know how to use it? In the next few pages, I hope to give you some insight into ways to use your EDM for fun and perhaps actually make money.

Electrode materials

The most commonly used electrode materials are graphite and copper. In the U.S. the primary material is graphite, in Europe I understand copper is widely used. The EDM machine described in this book burns with graphite, copper, and brass electrodes. The wide availability of these materials make them an excellent choice for everyday applications. About 90% of my work is with graphite as the electrode material. When graphite is used, it should be the type manufactured specifically for EDM applications. Carbon welding rods, carbon rods from batteries as well as motor brush material, and other forms of carbon and graphite are very poor choices; their use will be disappointing at best.

A good source for graphite in small quantities is the on line auction sites that often sell short pieces that are no longer useful for large commercial machines. Some retailers sell these “drops” as well.

The largest manufacturer and supplier of commercial grade EDM graphite is POCO. A good general-purpose
grade of Poco graphite to start with is sold under the name Poco EDM-2 and EDM-1. The Poco website is WWW.Poco.com

As mentioned earlier the generator used in this machine is not a state of the art design. Some specifications quoted for electrode performance may not apply to this machine.

Other suppliers of EDM consumables are listed below; most sell POCO graphite as well as less expensive EDM grade graphite.

Intech EDM
Broadview II
1-800-323-0295
http://us.gfac.com/intech/

Saturn Industries Inc
Hudson N.Y.
1-800-775-1651
http://www.globalspec.com/Supplier/Profile/SaturnIndustries

An industrial supplier that carries EDM electrode material, as well as a fair selection of EDM consumables is

Manhattan Supply Company or MSC
1-800-645-7270
http://www1.mscdirect.com/cgi/nnsrhm

Machining electrode material

Graphite is most commonly used to EDM steel; it is not normally a good choice to EDM carbide. Graphite may be machined, with common cutting tools, to the desired shape. It has good machine ability, although most grades are brittle and machining sharp corners should be done with care.

Graphite machining tips

If possible, use carbide tools for machining and keep the spindle speeds up; graphite loves to be cut at high speeds. High-speed steel tools may be used, but expect high tool wear. To reduce chipping, climb mill and reduce feed rate when about to exit a cut. When turning, typical roughing feed rates are .015, finishing should be around .005. Cut depths of 015-.020 are better than light .005 cuts. Use positive rake tools with a nose radius of at least 1/64”.

Graphite is very dusty and messy. Most people like to machine it wet to reduce the dust problem, but then you end up with a black abrasive slurry. I often use WD-40 when cutting and wipe the residue with a shop towel. If machined dry, use a respirator and a vacuum to collect the dust.

Roughing and finishing electrodes

In some applications, two electrodes are needed to finish a hole to a precise size. The first electrode is for roughing, the second electrode is the finishing electrode.

The roughing (or coarse) cut is usually made at a lower frequency, but with higher electrical energy being dissipated per discharge (higher capacitance). The higher discharge energy erodes not only the workpiece, but also the electrode (but to a much lesser degree), in particular, the sharp corners of the electrode. Once the hole is roughed out, a finishing electrode is used to bring the hole to size. I usually make the roughing electrode about .015-.020 smaller than the finishing electrode.

The high quality dense graphite manufactured today significantly reduces the electrode erosion problem on RC generators. Diodes D4-D5, see schematic diagrams on page 7 and 22, are to reduce electrode wear on RC generators.
These diodes block the “electrical ringing” that occurs after each discharge. This greatly reduces the electrode wear in RC generators. With the newer pulse EDM power supplies, the wear problem is virtually non-existent under certain machining parameters.

**Indexing electrodes**

In applications where two (or more) electrodes are needed to bring the hole to the correct size, the electrode holder on the servo ram should have a means for indexing (or aligning) the electrodes, to ensure that all the electrodes are properly positioned. In one-off jobs and temporary set up’s, a dial indicator may be used to check the positioning.

It is beyond the scope of this book to outline the details for building the complex tooling necessary to accomplish this indexing task. I will suggest that perhaps, the simplest method I have seen that gives predictable results is a “V” block and associated clamps for holding the electrodes. By using “V” blocks and square shank electrodes (or a round electrode with a flat cut on at least one side) good repeatability is possible.

In most cases, two “V” blocks are used. One of the “V” blocks is used off the ram to properly set up and/or hold the electrode for machining. The second “V” block mounts on the ram in place of the drill chuck. The “V” block and a clamp are used to hold the electrode. One of the leading companies in the EDM industry that builds indexing tooling is System 3R.

http://www.system3r.com/
973-785-8200

---

In the most basic design, they use a cylindrical arbor with a pin that rotates against a stop on the ram. The following photos show examples of their Mini electrode holders. The one on the left is a holder with a copper electrode attached. The holder on the right does not have an electrode attached to it; instead it has a large area for attaching electrodes.

**Stepped electrodes**

If the EDM ram has enough travel and the cut is a through hole, a stepped electrode provides for roughing and finishing in a single electrode i.e. no electrode indexing is necessary. The first part of the electrode does the roughing and the second step (mirror image of the small section) on the electrode is sized for the finishing cut.

Since the EDM process is a slow metal removal process, it is advantageous to remove the bulk of the metal via conventional machining processes, if possible. An example of this would be when a 1/2” square hole is required. By drilling a 7/16” through hole, most of the metal is removed. The electrode would only need to square up the hole, not remove all the material. Of course, if the workpiece is hardened, EDM may be the only choice for all of the metal removal.
Overcut

Because the EDM process always produces a cavity larger than the electrode, the electrode must be slightly smaller than the specified cavity dimension. This size difference is called overcut. The overcut can vary from a few ten thousandths to a few mils, depending on the gap voltage, the power level (discharge energy), and the dielectric condition. As the gap voltage or power level increases, so will the overcut. The number to know is the amount of the overcut. Once known, overcut is predictable, assuming the dielectric conductivity does not change a large amount.

To determine the overcut, make an electrode and perform a burn. Then measure the difference between the electrode diameter and the actual hole diameter. With this information, it is possible to calculate the undersize of future electrodes. My experience indicates, with the EDM generator outlined in this book, the overcut is generally .004-.008.

Recast layer

In the EDM process, material is removed from the workpiece by thermal action. This results in a layer of melted and solidified material on all cavity surfaces, known as recast. The recast is brittle and forms because the metal is heated to the melting point and then quickly quenched; cracks may develop in this recast surface.

The recast surface may be in excess of 65 Rockwell (Re) hardness. The recast is usually between .00001” and .002” thickness. Higher energy-per-pulse (i.e. coarse burns) will generally leave a thicker recast layer. If machining of the EDM surface is required by conventional methods, be aware of the hardened surface.

Electrode polarity

Ram, also know as sinker machines, use both positive and negative polarity, depending upon the application. The electrode polarity describes the polarity of the burn. Polarity can affect speed, finish, wear, and stability. In most cases, positive polarity (electrode positive) will machine slower than negative polarity. Despite this disadvantage, positive polarity is often used to protect the electrode from excessive wear.

When a significant amount of time has been invested in the fabrication of the electrode a bit of instability and reduced cutting speed can be tolerated, to conserve the electrode. Some electrode workpiece polarity combinations work better than others. In some cases, only one workpiece electrode polarity combination will give a stable burn.

Metal removal rates

The rate which metal is removed is determined by several factors. Generally speaking, the larger the capacitance being discharged, the faster the removal rate. Other factors are flushing (gap contamination), the type of electrode material used, the composition of the workpiece, as well as the electrode polarity. Materials such as nickel, chrome, molybdenum, and other alloys sometimes slow down EDM metal removal rates. A typical burn rate for the EDM described in this book is about .006 per minute for a 3/8” round electrode.
Dielectric fluids

For the small shop, you may use common kerosene or lamp oil as a dielectric, it is easy to obtain and relatively low in cost. If you feel to use a commercial dielectric fluid, purchase is possible in small quantities (1-5 gallons) from many industrial suppliers. When purchasing commercial fluids, I recommend getting the dielectric designed for fine and/or finishing work, such as Rustlick EDM-30, or similar. Dielectric fluid generally cost about $20-23 per gallon (2005). The fluid is available from most of the listed EDM suppliers as well as MSC.

Flushing

A critical factor in successful EDM work is the removal of particles from the gap between the electrode and the workpiece. Good flushing is key to good machining and surface finishes. There are three rules for good EDM work: 1. Flush 2. Flush 3. Flush

Poor flushing will result in erratic metal removal, rough surfaces finishes, and increased machining time. Of all the functions performed by the cutting fluid, the removal of particles, or swarf, is the most important. If the swarf is not properly flushed from the gap, the gap becomes overly conductive. Efficiency drops off sharply, surface finish is poor, and shorting conditions occur more frequently. Basically, the flushing operation is as follows: (1) clean dielectric is forced, either around the area where the electrode enters the workpiece (known as jet flushing), or through a hole drilled in the electrode (known as pressure flushing) that exits into the arc gap. (2) the dielectric is then removed from the work tank area and filtered.

Jet flushing

The most simple and least effective (though most often used by homebuilders in particular) flushing method is jet flushing. If a shallow through, or blind hole, is burned in the workpiece, jet flushing may be used. It is flushed by forcing dielectric from a nozzle into the area around the electrode workpiece interface; see drawing below. It's advantageous to extract the electrode occasionally to permit clearing of dirty dielectric fluid, this improves stability, speed and finish.

Through electrode pressure flushing

One of the most common and efficient flushing methods is through electrode flushing. In pressure flushing, the dielectric pump forces clean dielectric fluid through a hole in the electrode. The drawing page 106 shows a method that facilitates this technique. An end adapter (with the small 2-5 deg) taper, is inserted into a side hole which intersects with the flush hole/s drilled in the electrode. The other end of the adapter is inserted into the flexible flush line that slides over a 1/8" plastic Loc Line nozzle. At one time the tapered end adapters were sold by EDM suppliers but they no longer appear to be available. One possible options is to use
plastic vacuum line connectors sold in automotive supply stores. File or machine a taper on these connectors to fit into the small hole drilled in the electrode, otherwise it’s necessary to manufacture your own adapters.

The hose used to carry dielectric fluid to the electrode should be flexible to avoid deflecting the electrode. I have use rubber automotive vacuum line tubing. It is low in cost, readily available, very flexible, the down side is it tends to degrade after continuous exposure to most dielectric oil.

Thru-electrode flushing leaves a core of metal extending into the flush hole, in the electrode, as shown in the photo and drawing on this page. The problem with the core is it restricts dielectric flow. With deep holes, it’s necessary to extract the electrode and break the core off.

The pressure flushing method is easy to accomplish and supplies clean fluid to the arc gap. The correct pressure and flow of dielectric through the gap is critical for burn stability. To high a pressure, or to much volume, can cause an unstable burn. Often I start with jet flushing then switch to pressure flushing after a few minutes. Pressure flushing has several problems associated with it. One problem is that it causes taper to develop in the burned hole. As the dielectric leaves the arc gap area, it is swarf laden. The dielectric and swarf are forced between the electrode and the workpiece (in the overcut area). This creates sparking along the side of the electrode as it exits, and will create slight tapers as shown in the second drawing (exaggerated) on page 106.
One way to reduce the core problem is to drill flush holes in the bottom of the electrode at an angle to the main feedhole. This is shown in the drawing below. By doing this, the cores are mostly burned away as the cavity is formed.

The best conditions for pressure flushing are when a sealed flushing condition exists. Sealed flushing is when the whole face (end) of the electrode is in a closed burn cavity. This condition forces the dielectric to flow completely across the face of the electrode as it removes swarf. When burning a thru hole, the whole electrode face is initially in the burn pocket. As the electrode starts to break through, the sealed flush condition is lost, the burn becomes unstable, and the dielectric quickly escapes thru the hole which is being burned.

The simplest solution to this problem is to mount the workpiece on top of a sacrificial metal block and clamp it in place. As the electrode burns thru the workpiece, the sacrificial metal block maintains the sealed flush condition. This method will result in the shortest burn time, most stable burn, and best surface finish.

Another common case where sealed flushing does not exist is when doing a finished burn on a thru hole that has already been roughed. One solution to this problem is to place the workpiece over a piece of metal that has a pocket drilled or milled into it. The electrode will exit into the drilled hole. Using this method, the pocket should be completely filled with dielectric fluid prior to placing the workpiece over it. The workpiece must completely cover the hole in order to seal it off.

**Pot flushing**

A second means of pressure flushing is shown below; it is pot flushing. A pot or plenum is provided below the workpiece. Dielectric fluid, under pressure is forced into the pot and through the gap via a hole drilled in the workpiece. This method is especially convenient in mold making, where drilled ejector and/or core pin holes are already in the workpiece. Pot flushing is excellent to use with long or thin electrodes, that are difficult to drill flush holes through.

**Suction flushing**

If flushing is accomplished by suction, as shown in drawing on page 110, the tapered electrode and workpiece problem is greatly reduced. Although this is the preferred flushing method, it is more difficult since it requires a means of drawing (sucking) the fluid through the electrode.
Unfortunately, the dielectric tank/pump described earlier in this book does not lend itself well to this method of flushing.

**Trepansing**

Should there be a large area of metal to remove, and it is a through-hole, time can be saved if you use a trepanning electrode see drawing below. Trepansing is a "holed out" or tubular electrode used in through-hole machining to remove a large amount of material from the solid workpiece. A core is formed during the cut and drops out when the electrode penetrates the workpiece. Trepansing is always the fastest method for creating large thru-holes.

Remember a good flushing system will make a poor EDM generator look good, a poor flushing system will make a good EDM generator look bad, Flush Flush Flush.

**Tips and tricks**

In some applications, it is beneficial to mount the electrode on the work plate and attach the workpiece to the platen (the insulator block on the servo slide) assuming the workpiece is small enough. This arrangement simplifies the flushing process, as the swarf naturally falls out of the gap.

**Pressed arbor**

Many times, it possible to use small, lightweight thin electrodes to do the operation, see photo above. The graphite electrode has a hole in the center, and the brass (note the knurl) arbor is pressed into the hole, a round piece of graphite may be used in place of the brass. The brass piece has a hole through the center for flushing.

The electrode itself need not be large or thick to cut a pocket much deeper than its thickness. This design also
minimizes hole taper. The 1/8" thick electrode was used to burn the gear shape 1/4" deep into a hardened workpiece, for a plastic injection-molding project.

**Glued arbor**

Another technique for holding electrodes is to glue them to an arbor, versus pressing them. Use superglue for the adhesive and mix graphite dust with the glue. The graphite dust provides a conductive path for the current to flow through. The glue bond needs to be electrically conductive with less than 1 ohm resistance, check with ohm meter. **Tip:** if your fingers are glued together with superglue, acetone is the solvent that dissolves it.

**Glued together electrodes**

Sometimes it is faster and more cost effective to make electrodes in parts and then glue them together. Use the super glue and graphite dust combination described above for glued electrodes.

**Carbide insert tool holder**

Another very useful application of the EDM process is burning the pockets to hold carbide tool inserts. Often carbide inserts are found on the internet auction sites for very reasonable prices. Many times, these are discontinued inserts so the inserts are sold cheap. The problem is holders for these inserts often are difficult to locate and expensive. With an EDM machine this becomes a mute point, in fact, it has the potential for being a real moneymaking sideline.

Attach the actual carbide insert to the end of an arbor, via the described glue method, and use the actual insert as the electrode material, as seen on the right in the photo below!! This will give a perfect match to the inserts. It takes about 15-20 minutes to burn an insert pocket.

All that is needed to finish the holder is to machine a finger to hold the insert in place. Of course, it is possible to make a graphite electrode of the required shape and burn the pocket. The graphite electrode will give a slightly better surface finish than will the carbide electrode.

**Multiple electrode burns**

It's possible to burn multiple holes at the same time with an EDM. Let's assume five, 3/16" holes are needed in a part. Instead of burning each hole individually, make an arbor with five electrodes attached. The electrodes may be machined from one piece of electrode material or individual electrodes can be glued or pressed into an arbor. There is no increase in burn speed using this method. It will take five times longer to burn than with a single electrode. However, you will save set up time and minimize the chance of losing position, by accomplishing the task with one set up.

During the burn, if any of the electrodes short, all five will retract, as they are all attached to the same arbor. The generator only creates one spark at a time; it will spark at the first ionized gap. In the end, things average out to equal burn depths, assuming good flushing.
Broken screw and bolt removal techniques

To remove broken screws, bolts, studs, etc. (in many cases), it is not necessary to burn the complete broken item out. I have, on occasions, made a six-sided hex electrode and then burned a hex shape in the broken part. Once deep enough, insert a standard hex key and remove the part. Screw driver slots may also be burned into broken parts to assist in removal. When removing a broken tap, make a trepanning type electrode and just cut through the flutes in the area where the chips normally collect.

A money making job

One money making job I did for a customer was burning blind 1/4” keyways in 48 (existing) commercial tool holders with 3/4” bores. The holders were hardened and the blind keyways made conventional machining extremely difficult. I made an electrode of the required size and length. The parts were positioned horizontally and the electrode (which was horizontal) was extended into the tool holder’s bore. Instead of making the cut down to the 6 o’clock position, I chose to move the servo up toward the 12 o’clock position. This made flushing much easier, as the swarf “fell out” of the cut area. To accomplish this, I rewired the servo to cut going up, instead of down. It is nice to understand the design of the machine so that these kinds of changes are made with ease.

Non-conventional EDM work

The following example is a case where the best EDM conditions are not possible, but it was the only option. A 24-cylinder diesel engine shipboard was down with a broken head bolt. The service person tried to remove the bolt, he ended up with an easy-out broken off, then he attempted to drill it out. Yes, a broken drill bit was also in the mix. With an EDM and small servo heads, such as you have built, it is possible to perform the operation in a remote location.

Make a temporary fixture (“C” clamps, magnetic bases, weldment, etc.) to hold the servo head in the proper position. Around the location needing the EDM work, build a dam using putty (clay) designed for sealing ducts in HVAC systems (shipboard, it is called monkey poop). Fill the dammed area with dielectric and start the cut. The cutting area is flushed with a turkey baster to pump fluid in around and through the gap.

After a period, the swarf laden dielectric should be replaced with fresh dielectric. In some situations, I have actually supplied clean dielectric to the gap by running small plastic tubing from a pump in a storage tank and collected the dirty dielectric in another tank. Let the dielectric sit over night and most of the swarf will settle out.

Another dielectric that maybe used with some success is distilled water. Use it only where there is good ventilation, as the possibility of (explosive burnable) hydrogen generation is ever present. Use the distilled water as a single pass waste water system; it will quickly become contaminated and not work. The nice thing about water is it can be wasted. Only the gap needs to be submerged to perform a successful EDM burn. Performing such an EDM operation means no dielectric tank or dam is required. Use your imagination, there are a lot of ways to skin this cat.
Chapter 15

Your first burn

It is time for the first test burn.

[ ] Securely attach a steel workpiece to the plate in the work tank, via clamps, vice, etc.

[ ] Secure the EDM head on the holding device, if it is attached to drill press or milling machine secure the spindle so that it will not rotate or move.

[ ] Turn off all electrical power to the drill press or milling machine. I have found myself wanting to turn the spindle on when performing any work on these machines, habits are hard to break, at least for me. It is not fun playing helicopter with the EDM head! Ask me how I know?

[ ] For the first burn, use a 3/8" (or larger) piece of round graphite for the electrode. Make a hacksaw cut through the center to make the EDM cut a little more interesting.

[ ] Insert the electrode into the electrode holder (i.e. the drill chuck).

[ ] Attach the generator lead clips, positive to the electrode, or the arbor holding the electrode, and negative to the workpiece. Plug these leads into the generator.

[ ] Position the electrode approximately 3/16” above the workpiece.

Caution: should you come in contact with the electrode and the workpiece when the generator is turned on an electrical shock is guaranteed!!

[ ] Use jet flushing to keep things simple. Position the flush nozzle to flush across the workpiece surface.

[ ] Fill the dielectric tank with fluid. The workpiece should be submerged at least 1” or more under the dielectric to prevent a fire hazard. Make sure the filter pump (assuming it is submergible) is completely covered with fluid for cooling purposes.

[ ] Turn on the circulating pump

[ ] If, in the very unlikely event there is a fire, have a fire extinguisher ready at hand that is recommended for oil fires. I have never had to use an extinguisher on an EDM fire. My experience has been that as soon as the generator is switched off, the fire extinguishes itself; your experience may differ. You have been warned and I am not responsible for any disaster because of fire or electrical shock.

[ ] Turn the finish and coarse capacitor switches on to apply the full capacitance across the gap for this first burn.

Capacitor switch operation

There are three cutting capacitors in the machine, two maybe switched in and out of the circuit. For the finest workpiece surface finish (and the slowest least stable burn),
both capacitor switches are turned off. With the “finish capacitor” switch (SW2) turned on, the C1 capacitor is connected in parallel with the non switched C2 capacitor. The cut will be a little faster and the surface finish will degrade. With the “coarse capacitor” switch (SW3) on, the photo flash capacitor is switched in the circuit. The cutting speed significantly increases and the surface finish is much coarser.

The capacitor switches should never be switched on and off when an actual burn is taking place. If the capacitor switches are switched during a burn, expect the life of the switches to be greatly decreased. The switches may actually weld themselves together or be disintegrated in a way similar to the workpiece. Always withdraw the electrode and/or extinguish the arc, and then toggle the switch on or off. The arc maybe extinguished by turning the AC power switch off.

**Servo switch and reference potentiometer operations**

When the servo switch (SW4) is turned on, power is applied to the servomotor. The bicolor LED (D3) will switch from red to green depending on the polarity of the motor current. **In this section, green LED means ram advances and red means the ram is retracted.**

[ ] Turn the AC on.

[ ] Turn the servo switch (SW4) on.

[ ] Rotate the reference pot (R5) until the LED is off.

[ ] If you have not previously set up your motor, go to page 58 and 74 and follow instructions on setup and testing of the servomotor.

[ ] Plug the servomotor into the generator, the motor should not move.

[ ] Rotate the reference (R5) control left and/or right to get the servomotor to drive the electrode toward the workpiece i.e. green LED. If it is glowing red, no problem, it will not effect the burning. Just remember which direction is down for your machine.

[ ] When the electrode comes within one thousands (.001) or so of the workpiece an electrical arc should automatically be established.

[ ] Adjust the reference control pot (R5) until a stable burn is obtained (usually about 25-30VDC), i.e. you hear a sound similar to frying bacon with few or no interruptions. With a stable burn the LED flickers green, but expect to see an occasional red flicker as the control circuit corrects. When a direct short occurs, the LED will be full red until the short is broken, then full green until the arc is reestablished. Try to avoid a yellowish color of the LED if possible. The machine works with a yellowish LED but it causes the temperature of the motor driver chip to elevate which is not a preferred condition.

Should the servo start oscillating, adjust the reference control (R5) to increase the gap voltage until the servo stabilizes. As the burn progresses from time to time, a shorted condition will occur, it’s inevitable, the servo automatically retract the electrode to break the short, then reestablish the burn at the preset voltage

**Note:** If you have the window pot. (R11) mounted on the panel (optional, see page 16). Set the reference control for a steady burn then turn the window pot (R11) till the LED gives a yellowish color, then back off to a green flicker.
Through experimenting with the ref. pot. (R5) and the window pot (R11) you will quickly develop a feel for the setting that obtain the most stable burn condition.

The photo above shows a burn-taking place. It is common to see smoke hanging above the dielectric during the burn and bubbles forming in the fluid. Often you will be able to see the submerged arc. The gearmotor on my head has the motor shaft visible. I find it fascinating to watch the shaft pulse and some times “twitch” back and forth during a stable burn, imagine manually adjusting that gap! It can be done, but is not fun for very long.

[] Let the burn continue for about 5-10 min. Turn the AC off and make sure the capacitors are fully discharged at the end of a burn, or before changing electrodes. Use an insulated wire to short from the electrode to the workpiece after the generators turned off. Drain the fluid, remove the workpiece, and observe the cut. The photo on page 121 shows the suggested first burn.

[] You may want to experiment with different surface finishes by doing another burn with different capacitor switch combinations. Remember to turn the generator off or retract the electrode before changing the capacitor switches. You are now an official EDMer!! Be creative and try different electrode sizes and materials. Try different workpiece materials: hard stuff as well as soft stuff (those are technical term, you know). Don’t forget to try reversing polarity if the burn is unstable. Just experiment, have fun you may even make some money with this EDM thing! Few people have this capability in their shop, let alone their basement. Why not join the Yahoo users group and post a few photos of your machine.

http://tech.groups.yahoo.com/group/EDMHomeBuilders/

Sample EDM burns

All of the examples shown use the EDM system outlined in this book. The photos on page 122 show part of a file with several sample burns made in it, along with the electrodes which were used. The cuts made serve no purpose, other than to illustrate the capabilities of this small machine. The burn on the left is a 1/2” blind hole with protrusions into the circle.
The specifications are CCW (about 11 clock position) 3/16” square, 1/16” square, and a 1/8” square with a radius end. The latter has a 0.043 diameter hole cut through. The small hole took about 4 minutes using only the 20uf finishing capacitor. The electrode for the small hole was tungsten carbide. The burn with the tungsten Carbide was not extremely stable, but was accomplished. **Note:** with the Window Pot (R11) upgrade this burn is much more stable!!

The second burn is a blind hole and a through hole made with a single electrode. The “D” shape is 17/32” across the flat side. The off-center boss is 5/16” diameter. The file is a little over 1/8” thick. Both burns were extremely stable with the noted exceptions. Each burn took approximately 12 minutes each. The photo to the right on page 221 shows the back side of the same file.

The photo on page 123 is a C-6 cemented carbide, with a hole through the carbide. The burn of the carbide was not very stable and the progress is rather slow. Remember, carbide is a semiconductor, which makes cutting it difficult.

I find that a copper or brass electrode burns very nicely into carbide but expect considerable electrode wear.

**Appendix**

**Voltmeter faces**
Purchased Printed Circuit Board info

As mentioned in the front of the book Printed Circuit Boards (PCB) are available for $25 each. This price is subject to change depending on manufacturing and shipping cost. The quoted price includes postage and handling to any U.S. address. If you do not have a U.S. address contact me at the email or mailing address listed below and I will advise of cost for the board and shipping by 1st class air mail to your country. I accept payment via Paypal, sent to the following Email address:

bnfi@mail.uark.edu

If you prefer sending money order or cashiers check make it payable to Ben Fleming.

The mailing address is:

Ben Fleming
1734 N. Viewpoint Dr.
Fayetteville AR. 72701 USA

The board is designed to be a drop in replacement for the one described in this book. For most people, if you have all the parts, it will taking about an hour to complete the board wiring and verify the voltage readings. The board ships with instructions for assembly and testing. I am not going to cover that procedure in this text as it is subject to change with any upgrades to the board.

The complete EDM electronic parts list

This is a complete list of parts required for the EDM described in this book with part number of items available from Radio Shack.

www.Radioshack.com
1-800-843 74225 and
Allied Electronics
WWW.alliedelec.com
1-800-433-5700

<table>
<thead>
<tr>
<th>Qty</th>
<th>Component</th>
<th>Radio Shack #</th>
<th>Allied #</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LM339 Quad Comparator</td>
<td>(276-1712)</td>
<td>735-1160</td>
</tr>
<tr>
<td>1</td>
<td>component P C Board</td>
<td>(276-168)</td>
<td>N/A</td>
</tr>
<tr>
<td>1</td>
<td>14 Pin DIP socket</td>
<td>(276-1999)</td>
<td>900-0006</td>
</tr>
<tr>
<td>1</td>
<td>16 Pin DIP socket</td>
<td>(276-1998)</td>
<td>900-0008</td>
</tr>
<tr>
<td>1</td>
<td>7812 fix (12 volts) regulator</td>
<td>(276-1771)</td>
<td>288-0264</td>
</tr>
<tr>
<td>4</td>
<td>.1uf cap. two/pkg. RS</td>
<td>(272-135)</td>
<td>862-2142</td>
</tr>
<tr>
<td>1</td>
<td>1000 uf 35VDC capacitor</td>
<td>(272-1032)</td>
<td>852-7058</td>
</tr>
<tr>
<td>4</td>
<td>1K ohm resistor</td>
<td>(271-1321)</td>
<td>296-4741</td>
</tr>
<tr>
<td>1</td>
<td>6.8K ohm resistor</td>
<td>N/A</td>
<td>296-6525</td>
</tr>
</tbody>
</table>

Radio Shack doesn’t stock 6.8K, a 4.7K (271-1330) is acceptable.

<table>
<thead>
<tr>
<th>Qty</th>
<th>Component</th>
<th>Radio Shack #</th>
<th>Allied #</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4.7K ohm resistor</td>
<td>(271-1330)</td>
<td>296-4769</td>
</tr>
<tr>
<td>1</td>
<td>10K-ohm resistors</td>
<td>(271-1335)</td>
<td>296-4743</td>
</tr>
<tr>
<td>5</td>
<td>33K ohm resistor</td>
<td>(271-1129)</td>
<td>296-6499</td>
</tr>
<tr>
<td>1</td>
<td>100K ohm resistor</td>
<td>(271-1347)</td>
<td>296-4745</td>
</tr>
<tr>
<td>1</td>
<td>100K Pot (meter trim)</td>
<td>(271-284)</td>
<td>970-0322</td>
</tr>
<tr>
<td>1</td>
<td>50K potentiometer</td>
<td>(271-1716)</td>
<td>754-2108</td>
</tr>
<tr>
<td>8</td>
<td>Terminals Blocks two/pkg RS</td>
<td>(276-1388)</td>
<td>502-0421</td>
</tr>
<tr>
<td>1</td>
<td>1.4 amp rectifier</td>
<td>(276-1152)</td>
<td>935-6268</td>
</tr>
<tr>
<td>1</td>
<td>6-amp rectifier</td>
<td>(276-1181)</td>
<td>266-0059</td>
</tr>
<tr>
<td>2</td>
<td>25VAC transformers</td>
<td>(273-1512)</td>
<td>227-0680</td>
</tr>
<tr>
<td>1</td>
<td>12VAC transformer</td>
<td>(273-1365)</td>
<td>967-8386</td>
</tr>
<tr>
<td>4</td>
<td>10 mm standoffs</td>
<td>(276-1381)</td>
<td>839-0950</td>
</tr>
<tr>
<td>1</td>
<td>knob</td>
<td>(274-402)</td>
<td>543-1100</td>
</tr>
<tr>
<td>1</td>
<td>115V SPDT on off switch</td>
<td>(275-603)</td>
<td>757-4021</td>
</tr>
<tr>
<td>3</td>
<td>mini toggle switches</td>
<td>(275-324)</td>
<td>58-0376</td>
</tr>
<tr>
<td>1</td>
<td>push switch two/pkg RS</td>
<td>(275-1547)</td>
<td>948-7195</td>
</tr>
</tbody>
</table>
Items not available from Radio Shack or Allied Electronics

Parts Express 1-800-338-0531
http://www.parterexpress.com/
2 20 uf capacitor #027-436
(see text note on page 23)

All Electronics Corp. 1-888-826-5432
http://www.allelectronics.com
1 100 uf@ 100VDC photo flash cap.

All Electronics frequently have photo flash capacitors in stock. Another option is to recycle the photo flash capacitor from a disposable camera. Most are rated for 120 uf @ 330VDC.

Parts list for servo head

Assuming you are not building the servo head, an alternative is to buy an aircraft trim servo. They may be purchased directly from the manufacturer.

The Ray Allen Company
Ph# 760-599-4720
http://www.rayallencompany.com/products/servos.html
There are two versions that I have used successfully, T2-10A has 1” travel
T2-12A has 1.2” travel
****
The above head is mounted on a piece of angle (see page 62)
1 1/2” x 3” x 1/8”
****
The following items are needed to build the servo ram

Small replacement 3/8” hand drill chuck
1" length of 1/2" square steel (brass preferred) key stock
****
3/8" diameter cold roll steel 4 3/4" long
****
Two part epoxy glue, such as JB weld (see page 68)
****
Nylon washer and wavy washer
****
3/4" square x 1 1/4" long delrin, nylon or similar plastic
****
3/4" square steel tubing 3 1/2" to 5 1/2" long (not critical, see page 70)
****
3/8" bolt 3" long
****
1 1/2" diameter stainless steel hose clamp
****
The mechanical slide is made from a modified drawer slide. Knape & Vogt KV1129PZC16 rated for 35 pounds.
****
Pittman 12VDC gearmotor or similar (page 64) are available from surplus suppliers listed in the Appendix.
****

Parts list for dielectric tank

The tank is available from the following suppliers

U.S. Plastic corp. 1-800-809-4217
www.usplastic.com

The U.S. Plastic number stock number for the Toteline tank suggested is 51005. A smaller tank 17 7/8 x 11 1/4 x 6
(which works well with a single filter, but requires custom design work to mount the filter) is also available. The U.S. Plastic stock number is 51083

MSC Industrial 516-812-2000
http://www1.mscdirect.com/cgi/nmsrhm

McMaster-Carr supply 630-834-9600
http://www.mcmaster.com/
****
Thru-Hull connectors (page 79) are available in straight and 90° elbows. The larger diameter, connectors are referred to as cockpit drains. The connectors should be available through local marine suppliers. The Attwood company list them on their web site.
http://www.attwoodmarine.com
****
Plastic Welder 5 minute epoxy made by (page 81)
Devcon
Ph# 508-7771100
http://www.devcon.com
****
Grainger or Beckett pump (page 82)
Grainger model #2P407
Beckett model G600AVS
****
aluminum plate 12" X 15" X 3/8"
****
Dual and single filter mounts (page 83)
Jegs High Performance
http://www.jegs.com

The single filter part # is 771-111
The dual filter part # is 771-1221
Spacer block measuring 5 1/2 X 2 X 3/4"
****
Ping-pong ball
Threaded rod 1/4-20, a length of 9 1/2” required
Four 1/4-20 nuts and one 5/16-18 nut

A 2” length of 1/2-diameter aluminum rod with a thru hole

The following 3/4” PVC items are needed
Three feet of 3/4” schedule 40 PVC pipe

Two 90° elbows

An end cap to fit the PVC pipe

Three male and one female-PVC threaded couplers to match
the oil filter mounts and pump, most likely 3/4” NPT
at least one straight PVC coupler 3/4”

An adapter 3/4” NPT (pipe thread) to a garden hose thread.

A garden hose “Y” and straight shut off valve

Male brass 1/2” garden hose replacement end

A 3” length of 1/2” copper tubing and a 45 deg elbow

Two feet of 18 gauge solid copper wire

Household light switch, 120VAC Only use a metal
switchbox (page 87)

From the Loc-Line company
http://www.loc-line.com
Purchase at least one male 1/8” NPT valve, and one round
1/8” nozzle, and a foot of the Loc-Line (page89)

Angle iron 22”X 2X 1/8”

List of surplus houses

Below are a few of the surplus houses I’ve purchased from.

All Electronics Corp.
1-888-826-5432
http://www.allcorp.com

Surplus Center
1-800-488-3407
http://www.surpluscenter.com

C and H Sales Company
1-800-325-9456
Http://www.candhsales.com

Fair Radio Sales:
419-227-6573
419-223-2196
http://www.fairradio.com

Electronic Goldmine
800-445-0697
http://www.goldmine-elec.com/

Alltronics
408-778-3868
http://www.alltronics.com/

Jameco Electronics
1-800-831-4242
http://www.jameco.com/
Glossary

Ammeter - An instrument for measuring electrical current in amps.
Amperage - The amount of average current measured while cutting is taking place.
Ampere - The unit of electric current produced by 1 volt across 1 ohm of resistance.
Anode - The positive terminal of a cell. Often applied incorrectly to the EDM electrode.
Arc - A continuous flow of electrical current (also known as D.C. arcing) between the electrode and workpiece. It is an undesirable condition and is normally recognized by a yellow flash.
Arc suppressor - A circuit in the control section of an EDM machine that reduces the possibility of arcing.
Automatic depth finder - An electrical device that stops the EDM ram slightly above the workpiece and maintains that position.
Average current - The average value of all the minimum and maximum peaks of amps flowing in the gap.
Burning - A slang term for the EDM process.
Capacitor - An electrical device that stores a charge. It is used in some power supplies (mostly older) designs. It is also used occasionally in newer supplies to intensify the spark with increased electrode wear.
Carbon - A natural occurring material used to make graphite. Many times it’s used (slang) to describe the electrode material made of graphite.
Cathode - The negative terminal of a cell. Often applied incorrectly to the workpiece.
Circuit - A continuous path for the flow of electric current.

Condenser/condenser - An outdated term used to describe a capacitor.
Conductor - A material which will carry electric current.
Contamination - The accumulation of debris in the dielectric fluid which results in a decrease in the fluid’s dielectric strength.
Coolant - See dielectric.
Copper graphite - A graphite electrode material infiltrated with copper.
Copper tungsten - A porous tungsten material infiltrated with copper.
Core - The slug that remains after EDMing with an electrode that has a flush hole in it.
Corner wear - The wear which occurs on the corners of an electrode (the highest wear area).
Crater - The small cavities (pits) left on the surface of the workpiece by the EDM sparks.
Cubic inches per hour - The unit of measure used to describe the rate of metal removal from the workpiece.
Cut - To machine with the EDM process.
Cutting rate - Same as machining rate.
DC arcing - See Arc.
DC/Direct Current - Constant polarity current, as opposed to Alternating Current (A/C) which changes polarity from negative to positive in cycles.
Deionization - A return of the dielectric to a nonconductive state. Failure to reach this state is a major cause of DC arcing.
Depth of crater - The distance from the peaks to valleys on the workpiece.
Depth to diameter ratio - The ratio of the depth of a blind hole compared to the diameter of the electrode used to make the hole.
Diameter (dia) - The straight line distance through the center of a round object.

Diametral sparking distance - The difference between the electrode dimension and the dimension of the hole produced.

Dielectric fluid - A light oil which insulates the spark gap between the electrode and the workpiece until a high voltage ionizes the spark gap and causes it to become an electrical conductor. This ionization permits an electrical current to flow through the dielectric to the workpiece. The dielectric also serves to cool the work and to flush away the particles removed from the workpiece.

Dielectric strength - The voltage at which the insulating qualities of a material break down.

Discharge - The EDM spark.

Discharge channel - The conductive path formed by the ionized dielectric and vapor between the electrode and workpiece.

Dither - A vibrator motion of the electrode used to improve cutting stability.

Down feed - A control circuit to advance or retract the electrode.

Duty cycle - The percentage of the on-time relative to the sum of the on-time and off-time setting for a particular cut.

Edge finder - An electrically activated device to aid in the accurate location of the workpiece with respect to the electrode.

EDM - Electrical Discharge Machine or Electrical Discharge Machining. A metal removal process using a series of electric sparks to erode material from a workpiece.

EDG - Electrical Discharge Grinding.

Electrical resistively - The resistance of the flow of electricity measured in ohms.

Electrode - A tool used in the EDM process most commonly made of copper or graphite.

Electrode growth - A plating action occurring at certain low wear settings, which causes workpiece material to build up on the electrode, causing it to increase in size.

End ware - A reduction in the length of an EDM electrode during EDMing.

Eroding - Material removal by the EDM process.

Farad - The unit of electrical capacitance. One farad = a potential of one volt when charged by one coulomb.

Filtering - The removing of debris from the dielectric fluid before being pumped back to the work tank or through flushing holes in the electrode or workpiece.

Finish - The surface texture produced by EDMing.

Finish cut - The final cut made with EDM on the workpiece. The finer the finish the longer it will take for the finish cut.

Flashpoint - The temperature at which any flammable material will burst into flame.

Flush pot - A multipurpose box-like fixture, which is clamped to the machine worktable. It is primarily used when EDMing through-holes. The workpiece is clamped to the box top, (over a predrilled hole or opening) that will permit an electrode to pass through the workpiece with out interference from the tank's top plate. When connected to the dielectric system it can be used for either suction or pressure flushing.

Flushing - Flowing dielectric through the gap to remove the debris caused by machining with EDM.

Flush hole - A hole through the workpiece or electrode used to introduce dielectric fluid to the gap for flushing away debris.

Frequency - The number of cycles (on/off) completed per unit of time. Usually expressed in Hertz.

Gap - The distance between the electrode and workpiece. Also referred to as spark gap.
Gap voltage - This can be measured as two different values during one complete cycle. The voltage that can be read across the electrode/workpiece gap before the spark current begins to flow is called the open gap voltage. The voltage which can be read across the gap during the spark current discharge is the working gap voltage.

Generator - An old term for EDM power supply.

Graphite - The most commonly used material for EDM electrode in the U.S.. It has very high heat resistance and transfers electric current very efficiently. In Europe copper is the most common electrode material.

Head - The part of and EDM which houses the ram or quill.

Heat Affected Zone (HAZ) - Also called the "recast layer". The depth of heat penetration altering the parent materials metallurgical structure due to the EDM process. The depth ranges from .0002 to .008 depending on material and energy per pulse.

Hertz (Hz) - The international term for one complete electrical wave cycle. In EDM, the unit of frequency.

Hunting - An erratic bouncing movement of the ram during a cut caused by poor flushing conditions.

Injection flushing - An external flushing method also known as jet flushing.

Initiation voltage - Same as open gap voltage.

Insulator - A material (such as rubber) which blocks the flow of electric current.

Ionization - Generally accepted as a phenomenon by which the dielectric between two points on the electrode and workpiece become electrically conductive.

Ionization voltage - The voltage at which current flow begins across the gap.

Ionized path - The path of electrically conductive dielectric molecules (between the electrode and workpiece) through which the spark current will flow.

Lateral flushing - Same as surface, splash, jet flushing.

Low wear - Settings for EDM machining which produces a very low degree of wear on the electrode. In some cases less than 1% wear is possible.

Machining rate - Same as metal removal rate. The rate at which material is removed.

Metal Removal Rate (MRR) - The rate at which material is removed from the workpiece by EDM, in cubic inches/hour.

Microfarad - also uf One-millionth of a farad.

Micron micrometer - A unit of length equal to one-millionth of a meter.

Micro inch - One-millionth of an inch (.000001).

Microprocessor - A computer-on-a-chip. Found in all advanced EDM systems. The microprocessors provide many control functions.

Microsecond - One-millionth of a second (.000001).

Millisecond (ME) - One thousandth of a second (.001 sec.).

Miss - A pulse that does not produce metal removal.

Modular construction - In EDM a type of power supply where entire circuits are integrated on boards or modules. This makes possible rapid servicing and replacing.

Monitor - In EDM work, any mechanical or electrical device that is used to indicate various operating conditions.

Multiple electrode - The simultaneous use of two or more electrodes to produce cavities in workpiece/s.

Multiple lead power supply - One power supply with multiple independent power leads.

Nanosecond - One millionth of a second (.000001 sec.).

Non-directional finish - A finish having no specific direction to its surface pattern. An EDM finish is non-directional.

Normal polarity - Negative polarity to the electrode.

Off time - The time between sparks, measured in microseconds. To short an off-time may result in DC arcing.
Ohm - A unit of electrical resistance. Current flowing in a conductor of one ampere produced by a potential of one volt.
Oil through chuck - A sealed holder for tubular electrode through which dielectric fluid can be pumped or drawn.
On time - The duration time of the EDM spark measured in microseconds.
Open circuit - An electrical circuit that is not complete.
Open gap voltage - The voltage between the electrode/workpiece before current begins to flow.
Output - The voltage and current of an EDM power supply.
Overcut - An EDM cavity is always larger than the electrode used to machine it. The difference is called the overcut. Diametral over cut is most often used.
Pause - Same as off time.
Peak current - The maximum current available from each pulse from the power supply.
Percent electrode wear - The volume of electrode worn away as compared to the volume of workpiece worn away.
Platen - A large flat mounting surface affixed to the end of the ram of an EDM machine.
Polarity - In EDM, the designation of positive or negative electrical potential to the electrode.
Potential - The difference in voltage between two points of an electrical circuit.
Power supply - The part of the EDM system that supplies the voltage and current that causes the sparks or discharges between the electrode and workpiece.
Pressure flush - The forcing of dielectric through flush holes in the workpiece or in the electrode.
Pulse - The discharge of a quantity of electrical energy having preset voltage and amperage and expended over a preset time.
Pulse duration - Same as on-time.

Quench - The rapid cooling of the EDMed surface by the dielectric fluid.
Quill - See Ram.
Ram - The moving member of and EDM machine on which the electrode or electrode holder is mounted.
RC (relaxation) circuit - An outdated EDM power supply circuit that uses capacitors to store the charge that produces the spark at the gap.
Recast layer - A layer created by molten metal solidifying on the work surface.
Rectifier - An electrical device that converts alternating current to direct current.
Relaxation circuit - See RC circuit.
Reverse burning - The technique of mounting the electrode on the machine table and the workpiece on the ram.
Reverse polarity - A term used to indicate positive polarity to the electrode.
RMS (Root Mean Square) - An obsolete term used in surface finish measurement.
Rotating spindle - A device used on EDM machine used to rotate the electrode to achieve more uniform wear and to improve flushing conditions.
Roughing - The mode of EDM that removes the most material in the shortest time.
Secondary discharge - A discharge that occurs as conductive particles are carried up the side of the electrode by the dielectric fluid.
Servo-mechanism - The device that drives and controls the movement of the ram.
Side wear - The wear along the sidewalls of the electrode.
Silicone - A dielectric fluid for special situations consisting mostly of the chemical polymer silicone.
Solid-state power supply - A power supply that uses transistors in the circuitry.
Spark - An electrical discharge of very short duration between two conductors.
Spark erosion - Another name for EDM. Used primarily outside of the U.S.
Spark gap - The distance between the electrode and the workpiece when discharges are occurring.
Spark intensity - The amount of energy in the spark.
Split electrode - Multiple electrodes on a single machine electrically insulated from each other.
Square wave - A term for an electrical wave shape generated by a solid-state power supply.
Stability - The steadiness of an EDM cut.
Stepped electrode - An electrode constructed in such a manner to allow the roughing and finishing of a through-hole cavity in a single set up.
Stroke - The distance the ram travels under servo control.
Suction flushing - Using a vacuum to draw the contaminated dielectric away from the gap.
Surface finish - The relative roughness or smoothness of a machined surface.
Surface integrity - The quality of the machined surface and subsurface.
Surface flushing - The use of nozzles to direct jets of dielectric at the cutting area to flush away debris.
Surface roughness - Surface irregularities on a machined surface.
Taper - The dimensional difference between the entrance and exit opening of a through-hole cavity.
Through hole flushing - The use of a pre-drilled hole in the workpiece to inject dielectric fluid up toward the gap by injection flushing or down from the gap by suction flushing.
Timer - A control unit that controls spark on and off time.
Transistor - An electronic component used as a switch to turn electrical current on and off.

Trepanning electrode - A hollowed out or tubular electrode which is used in through-hole machining to remove a large amount of material from the solid to avoid pre-machining by conventional means.
Unstable - Erratic or intermittent EDMing.
Vacuum flushing - see suction flushing.
Vacuum tube power supply - An old power supply design which used vacuum tubes to switch the machine pulses on and off.
Vibrator - An accessory used to move the electrode back and forth rapidly primarily for improving flushing.
Viscosity - The tendency of a fluid to resist flow.
Voltmeter - An instrument that measures voltage.
Volumetric Wear - The total wear of the electrode expressed in cubic inches.
Waveform - A geometric display of the output of a power supply as seen on an oscilloscope.
Wear - The erosion of the electrode during the EDM process.
Wear ratio - The volume of electrode worn away as compared to the volume of workpiece material removed by EDM.
Wire EDM, WEDM - An EDM process where the electrode is a continuously moving conductive wire that moves in preset patterns around the workpiece.
Working gap voltage - See gap voltage.
Workpiece - Any part on which EDM is being used to cut holes or cavities.
EDM How-To Book

Here, a simple electrode has deeply etched the letters EDM into an incredibly hard file. This is something you can do by building a powerful EDM machine using the rare information you'll find inside this book.

Here, you'll discover...

- How to build an EDM generator.
- How to build an automated control system.
- How to build a low cost servo driven precision slide.
- How to build a dielectric tank and filtering system.
- How to use EDM techniques and tooling.

If you are a machinist, toolmaker, metal artisan, gunsmith, jeweler or just a tinkerer, you need to explore this powerful technology. It will allow you to accomplish tasks considered impossible. Until now.

WHAT IS EDM?

Electrical discharge machining uses an electrical discharge to etch metal submerged in a fluid. It's possible to machine in complex ways extremely hard metals with remarkable precision.

Briefly stated, EDM operates like this. An electrically conductive workpiece to be machined is submerged in a bath of oil. The generator's leads are connected to the electrode and workpiece. As the electrode, under the automated control, approaches the workpiece, the insulating ability of the oil decreases and a spark jumps between the electrode and the workpiece, melting a small amount of material. This process is repeated thousands of times per second. The shape of the electrode is reproduced in the workpiece. The hardness of the material is unimportant, but it must be electrically conductive.