Salvaging Interesting Gadgets, Components, and Subsystems

Introduction:

The purpose of this document is to help reduce the clutter in land fills :-).

Many dead appliances, and consumer electronic and computer equipment contain parts and subassemblies which are not only neat and interesting, but useful for various experiments and projects.

* I bet you tossed that big heavy slow 5-1/4" hard drive in the garbage when you upgraded, didn't you? Admit it! Did you know that if it was a high performance drive, it contained several of the most powerful permanent magnets you would ever be likely to find anywhere? And, they would have been free!

* That big old microwave oven? Too bad. More magnets, nice high voltage power transformer, rectifier, capacitor. Electronic or mechanical timer, fans, other motors, etc.

* What about that dot matrix printer? Too bad - at least two stepper motors, a nice power supply, and various other electronic and mechanical components.

* More steppers in floppy drives. Also, probably a regulated speed pancake motor.

* Old TV or monitor? Another mistake. The high voltage power supply was probably good for 12 to 30 KVDC at 1 or 2 mA. This is useful for many high voltage experiments, plasma globes, negative ion and ozone generators, bug disintegrators, starters for really LARGE HeNe lasers, etc.

There will be several types of information:

1. Where to obtain a particular type of part like a powerful magnet.

2. What dead consumer electronics, computer equipment, and appliances yield in the way of useful parts.

3. Unconventional uses for subsystems or common replacement parts or modules from such equipment.

Place to obtain sacrificial equipment:

So, where do you find the equipment from which to remove parts other than your basement, your attic, or those of your relatives or friends? Consider garage, yard, tag, estate, and other sales; thrift stores (which may even have a 'free' table); junk, salvage, and surplus yards (including those run by the Department of Defense!), the town dump and other landfills if they let you take things away, trash rooms of high rise apartment complexes, the curb on pickup day, college campuses around the end of the Spring term, and any other place where perfectly good equipment gets tossed in this throw-away society!

Of course, don't overlook high tech flea markets as well as ham and computer fests. Regular flea markets are usually overpriced (where do you think they get the stuff??) but sometimes you will be able to negotiate a great price because they have no idea of what they are selling!

Yes, we are a strange bunch :-).

DISCLAIMER:

The devices, equipment, circuits, and other gadgets described in this document may be dangerous. Much of it deals with potentially lethal voltages. Getting electrocuted could ruin your whole day. For really high voltage equipment, also see: Tesla Coils Safety Information.

We will not be responsible for damage to equipment, your ego, blown parts, county wide power outages, spontaneously generated mini (or larger) black holes, planetary disruptions, or personal injury that may result from the use of this material.

Neat magnets:

Two excellent sources of magnets are described below. These are at least as strong as the more well known speaker types, possibly much stronger, and generally easier to remove:

1. Microwave oven magnetron tubes. Go to your local appliance repair shop and ask - they just toss bad ones. Each one has two ring shaped ferrite magnets about 2-1/4" in diameter with a 7/8" hole, magnetized N-S on the faces.

   Surplus places typically charge $3 to $6 each for one of these magnets.

   Note: A few older magnetrons used AlNiCo magnet assemblies or even possibly electromagnets which are not nearly as interesting. However, you probably won't see any of these.

2. Large hard disk drives - especially full height 5-1/4" high performance types - e.g., Seagate WREN series or Micropolous boat anchors (the rare earth magnets in these are wicked). The magnets in small drives are even stronger but are, well, much smaller :-). A typical size for a large drive is about 1" x 1-1/4" by 1/2". Since almost no one wants such large slow

drives anymore, they are often found at swap meets or yard sales for next to nothing.

Surplus places may charge $12 or more for ONE of the magnets from a large disk drive (there are typically 2 to 6 such magnets in a disk drive)!

Here is a quick easy experiment to try with these powerful magnets: Slide one such magnet over a thick aluminum plate. What do you feel? Or, let a 1/8" x 2" x 12" aluminum plate drop through the intact yoke from a Seagate WREN series 5-1/4" full height hard drive positioner. What happens? Why? What material might produce an even more pronouced effect? Why?

For more things to do with these neat magnets, see: Neodymiumarium.

Caution: Both these types are powerful and will squash flesh as they suck all the bits off of your magnetic media! I am not kidding about the part about squashed flesh - with some you actually need a small crowbar to pry the assembly apart!

You will find that some of these magnets are painted. This provides some resistance to chipping though this material may be on the verge of flaking off or has already done so in spots. In any case, I further recommend that you add additional layers of a tough enamel (e.g., Rustoleum) or the plastic/rubber dip used to coat tool handles. Otherwise, chipping damage (at least) will result all too easily and the chips are just as powerful as the rest of the magnet.

Disclaimer: I will not be responsible when your spouse or parents come home to find the microwave or PC missing some key components and as dead as a brick!

Other sources of fairly strong magnets:
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3. Spent laser printer toner cartridges where the entire developer assembly is part of the cartridge (e.g., EPS-2 for Canon engines). These include a page-width ferrite magnet. However, expect to make a mess disassembling the cartridge as there will still be considerable toner remaining inside.

   WARNING: The toner is a possible health hazard. A good dust mask should be used while working on these. Also, do not vacuum what remains - static can set off a dust explosion - use wet rags or paper towels to clean up the mess! The coating on the photosensitive drum may also be a hazardous material.

4. Loudspeakers.

   * Smaller or older speakers use AlNiCo type magnets which are usually in the form of a cylinder (about as tall as it is wide). AlNiCo is an extremely hard metal alloy.

AlNiCo magnets are not as powerful as ferrite or rare earth types and are easily demagnetized (but just as easily remagnetized). Passing a stack of these through the center hole of a strong ferrite magnet will increase their strength dramatically - until they are separated from each other!

* Modern loudspeakers use ring shaped ceramic ferrite magnets (similar to those in a microwave oven magnetron - see the section: "Neat magnets". glued to the pole piece (yoke) assembly within which the voice coil moves. The ferrite is extremely hard but very brittle so care must be used to extract these from the yoke assembly - see the section: "Disassembling loudspeakers to get at the magnets".

5. Permanent magnet stepper and servo motors. These will use ferrite or rare earth magnets usually in strange shapes. Note: Removing the magnets may result in partial demagnetization (reduction in magnetic strength) as the rotor is part of the magnetic circuit. Therefore, I do not recommend this source. There is generally no practical way of remagnetizing the strange shapes involved.

6. Optical (laser) pickups from CD players, CDROM drives, and other optical data storage devices. These may have some very tiny, but strong, rare earth magnets in the focus and tracking actuator. However, it seems a shame to sacrifice a the beautiful mechanics in such a device just to get the magnets! Caution: Tiny magnets even more fragile than bigger ones!

Disassembling loudspeakers to get at the magnets:

For small speakers with AlNiCo type magnets (the magnets usually look like metal cylinders), careful prying with a sturdy screwdriver will usually break the adhesive bond and/or free them from the yoke assembly. Note: Use the proper tool for the job - not your dad's prized screwdrivers!) Unlike the ceramic magnets described below, AlNiCo types are metal and quite sturdy.

(From: Arie de Muynck (ademu@pi.net)).

For the normal black ceramic ring shaped magnets (and likely for some Ticonal 'iron colored') the trick is: heat the complete assembly slowly using a paint-stripper gun, or in an oven (thermal, not microwave!). The glue will weaken and with a screwdriver you can SLOWLY work them loose. Protect your fingers with an old cloth. Never apply too much force, the ceramic would chip or break.

Do not overheat them above the so-called Curie temperature or the magnet will loose it's power irreversibly. That temp depends on the material but should be way above the 120 C or so to soften the glue. If you want to experiment with this effect: use a piece of iron attracted towards a magnet, heat the iron with a flame and above a rather sharply defined temperature it will not be attracted anymore. The effect is used in some Weller soldering irons to stabilize the temp.

Note that the force of a bare ceramic magnet is not as strong as you might expect, the magnetic lines of the large area of the ring have to be bundled and guided though iron to a narrow gap to provide a proper magnetic field.

Scripto lighters and gas grill ignitors:

Some types of disposable lighters contain a piezo electric element (instead of a flint and wheel) which generates a spark to ignite the Butane gas. Pressing down on the activator drives an escapement which results in a bar hitting the piezo element.

The result is several thousand volts on demand with its output available at a couple of terminals. This can be used to trigger xenon tubes or even to start helium neon lasers (with the addition of a pair of high voltage diodes to form a charge pump). Or as a prod for small cattle, but I didn't say that :-).
For a discussion of the HeNe laser application, see the document: "Lasers: Safety, Info, Links, Parts; Diode, HeNe, Ar/Kr Ion Lasers".

Detaching the piezo assembly only requires bending back and removing the sheet metal shroud at the top of the lighter. The entire piezo unit then just pops out.

Gas grill ignitors are similar - and even more powerful. These are available as replacement parts at your local home center or appliance store. (Don't steal the one from the family gas grill - your dad won't be happy.)

Dangerous (or useful) parts in a dead microwave oven:

A microwave oven with its power cord cut or removed AND its high voltage capacitor safely discharged is an inanimate object. There are no particularly hazardous parts inside. Of course, heavy transformers can smash your feet and sharp sheet metal can cut flesh. And, the magnets in the magnetron may erase your diskettes or mess up the colors on your TV.

Some may feel there is nothing of interest inside a microwave oven. I would counter that anything unfamiliar can be of immense educational value to children of all ages. With appropriate supervision, an investigation of the inside of a deceased microwave oven can be very interesting.

However, before you cannibalize your old oven, consider that many of the parts are interchangeable and may be useful should your *new* oven ever need repair!

For the hobbiest, there are, in fact, some useful devices inside:

* Motors - cooling fan and turntable (if used). These usually operate on 115 VAC but some may use low voltage DC. They can easily be adapted to other uses.

* Controller and touchpad - digital timer, relay and/or triac control of the AC power. See the section: "Using the control panel from defunct microwave oven as an electronic timer".

* Interlock switches - 3 or more high current microswitches.

* Heavy duty power cord, fuse holder, thermal protector, other miscellaneous parts.

* High voltage components (VERY DANGEROUS if powered) - HV transformer (1,500 to 2,500 VRMS, .5 A), HV rectifier (12,000 PRV, .5 A), and HV capacitor (approximately 1 uF, up to 2,500 VAC, perhaps 3,000 V peak).

* Magnetron - there are some nifty powerful magnets as part of the assembly. Take appropriate precautions to protect your credit cards, diskettes, and mechanical wristwatches. See the section: "Neat magnets" and the document: "Notes on the Troubleshooting and Repair of Microwave Ovens" for more info.

DOUBLE WARNING: Do not even think about powering the magnetron once you have removed any parts or altered anything mechanical in the oven. Dangerous microwave leakage is possible.

Using the control panel from defunct microwave oven as an electronic timer:

It is usually possible to remove just the touchpad and controller board to use as a stand-alone timer with a switched output. Be careful when disconnecting the touchpanel as the printed flex cable is fragile. With many models, the touchpanel (membrane touchpad) needs to be peeled off of the front plastic panel or the entire assembly can be removed intact.

The output will control a 10-15 A AC load using its built in relay or triac (though these may be mounted separately in the oven). Note that power on a microwave oven is regulated by slow pulse width modulation - order of a 30 second cycle if this matters. If it uses a triac, the triac is NOT phase angle controlled - just switched on or off.

Useful parts in a non-working VCR:

* Motors: 1 to 6 motors of various types. Mostly these are cheap DC permanent magnet motors but the main capstan motor may be a high quality brushless type with electronic control on-board. The video drum motor is likely three phase with its own controller.

* Power supply: Outputs various voltages and may be used intact but will always
  contain useful components like transistors and diodes, transformer(s), and
  large capacitors.

* Tuner. Whether you can make this work without the rest of the VCR is
  problematic but worth a try.

* RF modulator. This usually accepts a DC voltage for power, a control voltage
  to select TV/VCR, and will output on channel 3 or 4.

* Miscellaneous electronic components including crystals, delay lines, video
  and audio ICs, pots, connectors, etc.

What can you build with it? One can never tell! :-).

Useful parts from a battery powered electronic flash:

For information on how these work, see the document: "Notes on the Troubleshooting and Repair of Electronic Flash Units and Strobe Lights" which also includes many sample circuits. Two popular designs from Kodak disposable camera flashes are:

* Kodak Funsaver with Flash Schematic.

* Kodak MAX Flash Schematic and Photo. All newer Kodak disposable cameras
  including the "Funsaver Sure Flash" and APS (Advanced Photo System)
  "ADVANTIX" appear to use a similar if not identical circuit but I haven't
  disassembled one of those as yet.

WARNING: The energy storage capacitor in even the tiny flash from a disposable camera may hold a painful, if not lethal, charge for days or longer. Always make sure to check and, if necessary, safely discharge this large capacitor before touching anything!

These units are found in both pocket cameras (regular 35 mm, older 110 or 126, as well as disposable 'single use' types), and external flash units. Larger, more sophisticated models will have proportionately larger components but the basic circuits are very similar. The major parts present in all units include:

* Chopper transistor - high gain power transistor to drive the inverter.
  For pocket cameras, typical part numbers are: 2SD965, 2SD879, 2SD1960, etc.
  These are low voltage (20 to 40 V) NPN (though some may use PNP), high
  current (e.g., 5 A), with Hfes in the 400 to 600 range.

* Inverter transformer - Generates the 300+ VDC to charge the energy storage
  capacitor. Includes a primary drive winding of 5 to 15 turns, similar
  feedback winding (maybe), and 1,000 to 2,000 turn high voltage secondary.

* Energy storage capacitor - 120 to 500 uF or more, 330 to 400 V, photoflash rated (rapid discharge) electrolytic. Note: These usually do not have a high temperature rating - 55 DegreesC typical. WARNING: Can be lethal if even partially charged!

* Neon (normal or 200 V breakdown) or other ready indicator.

* Trigger transformer - generates a 4 to 8 KV pulse to fire the xenon tube from a small 150 to 300 V capacitor discharge. Includes a primary of about 12 turns, secondary of 350 to 450 turns.

* Xenon flashtube - usually between 1 and 2 inches in length. These require a 300 to 400 V energy storage capacitor, 4 to 8 KV trigger, and can handle 10 to 30 W-s flash energy.

Automatic types will have additional components including the following:

* Quenchtube - looks like an oversize neon light bulb but filled with xenon and triggered in a similar way to the main flashtube.

* Trigger transformer for the quenchtube - similar to the main trigger transformer.

* Thyristor (SCR) - in series with the flashtube used in energy conserving automatic flash unitsx.

* Photosensor - used to read light reflected from scene to set exposure.

There will also be a variety of other small electronic components possibly including fancy microchips in TTL (Through The Lens) programmable units. Also see the document: "Various Schematics and Diagrams" for possible useful modifications to inverters like the one from the Kodak MAX Flash.

How do I make a harddrive motor spin?:

You are tempted - those spindle motors that are part of the same large old clunky harddrives that yield really powerful magnets look like they would be perfect in that next robotics project if only you could figure out what all those darn wires were for!

(From: Bob Weiss (bweiss@carroll.com)).

These motors are usually brushless DC, and can be a pain to figure out. Windings are usually 3-phase wye. DC power applied to center tap of wye, and ends of windings go to output transistors/fets in the driver. Driven by 3 pulse trains 120 degrees apart. Other leads are for hall effect sensors that measure rotor position and time the drive pulses to the relative positions of the rotor magnets and stator coils. Not an easy driver to build from discretes! Some motors contain all the driver electronics, and only require +12VDC and a TTL enable signal to run. The Disc drive you took them out of will contain appropriate parts to build a controller, probably a driver chip from SGS or Sprague UCN series. Look up the chip in a databook for suggested circuitry. Best way to learn this field is reverse engineering!

High voltage power supplies from dead equipment:
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* TVs, monitors, and computer terminals all contain a source of high voltage for the CRT. Depending on the particular model, up to 30 KVDC or more at 1 to 2 mA will be available assuming the deflection/HV subsystem of your sacrificial equipment is in operating condition. However, you cannot (or at least should not) just string HV wires from the back of the family's 35 inch TV to your lab :-).

  - How much circuitry you actually need (and what you will have to add) depends on design but figure on the mainboard with the deflection drive and flyback, and probably the yoke (to keep the system properly tuned though this may not be essential).

    Some capacitance on the HV output may be needed as well (though the ones I have tried were happy enough with just the stray capacitance of the wiring). Originally, the CRT envelope provided this capacitance.

    See the section: "Why the yoke is needed to keep the horizontal deflection system happy".

  - Power will either be the AC line (WARNING: Very dangerous) or a DC supply (typically 12 to 24 VDC). They will usually operate on somewhat lower input voltages with correspondingly reduced output.

  - A 555 timer based oscillator or other horizontal sync source may be needed as well if the system doesn't free-run at close to the normal horizontal scan rate. This is probably easier where the guts came from a monitor or terminal (since a separate TTL compatible horizontal drive input is likely to be available) but it should be possible to fake out a TV as well.

  - Depending on design, these may require signals like 'HV Enable' and/or a feedback or reference voltage to operate properly.

  - Small B/W TVs, mono computer monitors, and computer terminals will provide about 12 to 15 KV.

  - Large B/W TVs and Color TVs and monitors will provide 15 to 30 KV. Even more from projection sets!

  - Some larger high performance color monitors may have a separate self contained HV module. One particular type (found in a 19 inch workstation monitor) is rated at 25 KV, 1.1 mA (and produces several other voltages) from a 26 VDC, 2.5 A power supply. However, by tweaking some internal pots, over 30 KV is available. See the section: "High voltage power supply module from Monitronix EZ series monitors" for one example.

One key advantage of using predesigned circuitry is that you are less likely to destroy power transistors and other expensive parts - and I have blown my unfair share :-(.

See the section: "Sam's super-starter(tm)" for a specific example of this kludge, um, err, approach for starting large HeNe laser tubes :-).

* The high voltage power supplies from plasma globes, electrostatic dust precipitators, photocopiers and laser printers, bug zappers, negative ion and ozone generators, electric fences, cattle prods, electric chairs, and other 'common' equipment may be pressed into service for your applications.

  Since these HV generators are not combined with anything else, they are likely to be self contained modules and very easily used by themselves.

  However, available current from some of these sources is generally less than from TVs or monitors. Details are left to the highly motivated student :-).

  - Plasma globes: Pulsed (not rectified or filtered) 10 to 15 KV.

  - Electrostatic dust precipitators: 5 to 10 KVDC.

  - Photocopiers and laser printers: Two outputs at 5 or 6 KVDC.

  - Bug zappers: 10 KV???.

Caution: Since these power supplies were designed for a specific purpose under specific operating conditions, their behavior when confronted with overloads or short circuits on the output will depend on their design. It may not be pretty - as in they may blow up! Take care to avoid such events and/or add suitable protection in the form of fast acting fuses and current limiting to the switching transistor.

Note about X-rays: Improper use of these sorts of devices may result in shock or electrocution, but at least you will not be irradiated at the same time unless you connect them to a something which includes a vacuum. In order to produce measurable X-ray radiation, electrons must be accelerated to high velocity and strike a heavy metal target. A high vacuum such as in a CRT or other vacuum tube (valve) is best but there may be some X-ray production from a low pressure gas filled tube. There is virtually none in sparks or arcs at normal atmospheric pressure. However, there will be UV and ozone which are both hazardous.

Sam's super-starter(tm):

This would be called a kludge by some, a Rube Goldberg by others. But, hey, as still others would say: "If it works, use it!". The original application was for starting LARGE HeNe laser tubes but there can be many other uses.

The entire horizontal deflection and high voltage sections of a long obsolete and lonely ASCII video display terminal were pressed into service for starting larger HeNe tubes. A source of about 12 VDC at 1.5 A is needed for power and a 555 timer based oscillator is needed to provide the fake horizontal sync:

* The deflection circuitry was all on one corner of relatively small board (about 3 x 6 inches). The flyback transformer is a plug-in unit. I left the other circuitry (vertical, video) in place since it is not powered by the same supply and therefore is pretty inert. However, if you want to recycle the parts.....

* The horizontal deflection yoke is needed to 'tune' the system - performance is much better with it installed. This wart looks a bit strange but is the easiest way to avoid modifying the design. See the section: "Why the yoke is needed to keep the horizontal deflection system happy" for more info.

* Horizontal drive is provided by a 555 timer in astable mode running at about 16 KHz (the original horizontal deflection rate of the terminal). A 10K ohm pot allows me to fine tune this for maximum HV output.

  Well, it turns out there was an unused spot on the board ready made for this circuit (well almost, at least there was a pattern for a spare 8 pin DIP! So, once the thing was basically working, I built the oscillator onto the board to reduce the clutter!

* Power requirements are modest - 10 to 15 VDC at just over 1 A. Over this range, the output varies between about 10 and 15 KV (what a coincidence!). Input down to about 5 VDC produces correspondingly reduced output but the circuit is not particularly stable over this lower range of voltages.)

I guarantee that "Sam's super-starter(tm)" - or its big brother, "Sam's hyper-starter(tm)" using parts from a color TV or monitor - will start ANY HeNe tube that can possibly be started! These also make nice self contained HV sources for other experiments :-).

Why the yoke is needed to keep the horizontal deflection system happy:

If you unplug the yoke (even if there is no interlock), while the system may still work to some extent but performance will be poor. High voltage will be reduced and parts may overheat (and possibly blow up).

(From: Jeroen Stessen (Jeroen.Stessen@ehv.ce.philips.com)).

Of course that doesn't work. The flyback capacitor is tuned for the presence of both inductances: line transformer and deflection coil. If you remove the deflection coil then the remaining primary transformer inductance is about 5 times as large. So, rule-of-thumb, you would have to decrease the flyback capacitor by a factor of approximate 5. But that's not all:

Without the deflection coil, a lot less current runs through the horizontal output transistor. So, in all likelihood, it will now be overdriven. So you need to reduce the base drive. But that's not all:

If you remove the picture tube capacitance and the deflection coil then all peak energy demand must be delivered from the primary winding of the line transformer. Even the shortest peak load will cause saturation. The parallel deflection coil will at least lend some temporary energy, and the picture tube capacitance does an even better job. A good high-voltage source without the benefit of a deflection coil is more expensive...

If you *must* get rid of the 'ugly' deflection coil, then you may want to replace it with an equivalent 'pretty' coil. But:

* It must be able to carry the peak current without saturation (a deflection coil has such a huge air gap that it can not possibly ever saturate, but a smaller coil can).

* It must have a low enough dissipation so you might have to wind it with litz-like wire (multi-stranded isolated), do not underestimate the losses in high-frequency coils, mostly due to skin- and proximity-effect.

* Yes, it can be done, good luck.

And you might want to add a discrete high-voltage capacitor. How to isolate the wiring (corona discharge!) is left as an exercise to the reader... (We pot them in convenient blocks).

High voltage power supply module from Monitronix EZ series monitors:

This is a self contained module (separate from the deflection circuitry) which makes it very convenient for your HV projects.

It is fully enclosed in an aluminum case about 1-7/8" x 6" x 5" with a 9 pin connector for the low voltage wiring and thick red wires with HV connectors - suction cup and Alden type - for the CRT 2nd anode and focus voltage respectively.

Manufacturer: Toyo, Corp., Japan

Model: HVP-1208A1-26L.

Input: 26 V, 2.5 A max.

Output: 25 KVDC, 1.1 mA
Focus, 4.5 to 7.65 KVDC, 15 uA
G2, 200 to 1000 VDC, 5 uA
-200 VDC, .5 mA

There are 8 pins installed on the 9 pin connector of which 6 were used. I wonder if the other 2 have any function other than spacing off the G2 voltage.

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     __________
    /          \
   <  o3  o6  o9 |
    >            |  View of connector on case.
   <  o2  o5  o8 |
    >            |
   <  o1  o4  o7 |
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Pin 1: -200 VDC (-184 VDC measured)   White or yellow
Pin 2: V+ in 26 VDC, 2.5 A max.   Green or brown
Pin 3: Power Gnd   Black
Pin 4: Shield Gnd   Bare or black
Pin 5: NC
Pin 6: NC
Pin 7: Enable (low) TTL   Orange
Pin 8: NC
Pin 9: G2 (+200 to +1000 VDC)   Red

I assume the NCs are truly not connected to anything and simply serve as clearance for the up to 1000 V G2.

In addition to the Focus and G2 pots, there is an unmarked adjustment accessible via a hole in the case. At first, this appeared to have no effect on any output.

When I opened the case, 2 additional pots come into view. While I do not really know their exact function, by advancing them clockwise, the HV could be boosted significantly. With both fully clockwise, the externally accessible control will vary the HV between about 27 and 32 KVDC regulated (only HV probe meter load).

High voltage transformers:
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* Neon sign or luminous tube transformers (same thing): 10 to 15 KV at 15 to 60 mA, current limited. Some may be higher. There are also smaller ones.

Current limited means that the transformer will deliver the rated current (Io) into a short circuit and produce the rated voltage (Vo) with no load. This is somewhat similar to being in series with a resistor equal to Vo/Io but implemented as a loose magnetic coupling so there is no additional power dissipation. (It isn't really this straightforward but will serve as a first approximation.) Therefore, a short circuit on the output will not blow a fuse or trip a breaker.

Sources: Your local sign shop, demolition company, or salvage yard. New: $100 or more. Used: $5 to $50 or free.

WARNING: Though current limited, the available current from neon sign transformers - especially the larger ones - is far into the range where lethal consequences are likely under the wrong circumstances.

* Oil burner ignition transformers: 8 to 10 KV at 10 to 25 mA, current limited. (See description for neon sign transformers, above.)

  Sources: Your local HVAC contractor probably for the asking as they are thrown out along with old oil burners when they are replaced. However, you will probably have to take the entire icky smelling disgusting burner assembly as part of the deal :-). However, there is will be a nice motor and small oil pump in there as well ;-).

  WARNING: Though current limited, the available current from oil burner ignition transformers is still more than enough to kill under the wrong circumstances.

Both neon sign and oil burner ignition transformer generally have centertapped secondaries connected to the case - which MUST be grounded (via a three wire cord and properly wired outlet) for SAFETY. Therefore, it is generally not possible to construct a totally isolated HV power supplie with these devices.

* Microwave oven transformers: 1.5 to 3 KV at .25 to .5 AMPS.

  Sources: Dead microwave ovens (the transformer is rarely the problem). Try your local appliance repair shop. However, you will probably have to cart away the entire oven - but other useful parts inside :-). See the section: "Dangerous (or useful) parts in a dead microwave oven".

  WARNING: The electrocution danger from microwave oven transformers cannot be overemphasized. They are not current limited, and even if they were, could be instantly lethal given the least excuse for a suitable path through your body since the rated current is a substantial fraction of an AMP at several thousand volts. Normally, one end of the high voltage secondary is bonded to the core - which must be grounded for safety. However, it may be possible to disconnect this and construct an isolated HV power supply (which will be only marginally less dangerous).

* Automotive ignition coils: 25 to 75 KV (depending on model) at low current.

  Sources: Your 1997 Honda. Just kidding :-). Auto repair shops or parts stores, salvage yards.

  WARNING: While unlikely to be lethal, the HV output of an ignition coil can still result in a seriously unpleasant shock and possible collateral damage.

* Flyback transformers from TVs, monitors, computer terminals, or other HV power supplies. Little teeny ones in CRT based camcorder viewfinders and older Watchman TVs. Output from less than 3 KV to over 30 KV at 1 to 2 mA depending on model. Most include a high voltage rectifier though some may use an external one or voltage multiplier (also a useful and neat device).

  For many hobbyist uses, the only portion of the flyback that is important will be the high voltage winding (and rectifier, if present). It is a simple matter to add your own drive and feedback windings on the flyback core. This eliminates the uncertainty of determining the number of turns and wire size for the existing windings.

  Sources: CRT based equipment tossed for failures NOT caused by a defective flyback. However, sometimes even a bad flyback can be used for HV projects. This will be the case if the problem is:

  - Shorted primary windings. With some flybacks, the primary windings are on a separate bobbin and can be removed. Even when buried, they can sometimes be extracted without affecting the HV winding (just don't lose the HV return!).

  - External arcing due to cracks or pin-holes. Try coating with RTV silicone or HV sealer (allow ample time to dry completely). Plastic electrical tape may work temporarily at least. Note: Try to get the type of RTV that is non-acidic. The normal kind (that smells like viniger when curing) may be corrosive to the wiring. However, I haven't seen problems with this.

  - Breakdown in focus/screen network. This section may be removable with a hacksaw or small chisel! Then, insulate the exposed HV terminals as above.

  - Shorted HV rectifier (rare). Just add an external HV rectifier if needed.

    If you really want AC, this is an advantage! In fact, it might be possible to deliberately short the HV rectifier where you want an AC source by passing excessive (DC) current through it and/or violating its PIV rating (but that may be tough as other parts are likely to fail first!).

  - Broken or cracked core. Substitute the core from another flyback or glue or clamp the pieces together (broken edges in close contact). Don't lose the mylar/plastic spacers and replace them (if needed) when the repair is complete!

No one actually buys flyback transformers for experimentation!

WARNING: Flyback transformers are capable of producing shocking experiences. However, when run at high frequencies, your first hint of bodily damage may be via your sense of smell - from burning flesh. Keep clear!

Note: Ignition coils and flyback transformers can generate very high voltages but must be driven by a pulsed or high frequency drive circuit. These cannot be plugged into the wall socket directly!

Also see the section: "Driving automotive ignition coils and similar devices".

Driving automotive ignition coils and similar devices:

"I have some questions about automotive ignition coils. I'm referring to the cylindrical "universal" type which has two 12 V terminals and one HV terminal in the center of the cap.

What is the typical peak output voltage and current?

What is the maximum average power input that such a coil can tolerate? I'm aware that the cross-sectional area of a transformer core dictates power handling capability. Judging from the skinny core in a spark coil, I'd place the maximum continuous duty input at around 50 watts. Am I in the ball park on this?

Is there an optimum pulse rate?

Do ignition coils employ any sort of current limiting?

Do "high-performance" coils with 45-75kv outputs offer significant increases in output power, or just higher voltage?"

(From: jfreitag@gsosun1.gso.uri.edu (John Freitag)).

First, be aware that the coil does not act as a transformer as such, even so called "Hot Coils" have only a 1:100 turns ratio which would give only 1,200 volts from a transformer. If you were to energize the coil with an AC voltage like you would with a transformer this is what you would get. An automobile ignition is more properly referred to as an "induction coil" Its output voltage is defined, not by the turns ratio but rather by the differential equation:

$$V = L\, di/dt$$

where:

V is the output voltage
L is the inductance in Henrys
di/dt is the rate of change of current flow as the field collapses in the coil.

V into an open circuit, will essentially rise until a spark jumps. When the air ionizes and the spark occurs the remaining energy in the coil sustains the spark.

Hot coils have a heavier primary so that they can pass more current, hence a higher di/dt.

The maximum pulse rate is determined by the time taken for the current to build when the points close (due to L it rises slowly until it reaches a steady state) and the time for the field to collapse when the points open. (the voltage to generate the spark occurs only after the points open and the field is collapsing)

I have never thought about the power in the spark but I suppose it would be:

P = (L di/dt) ^2 / R where P is the power in watts and R is the total resistance of the coil secondary, the plug wire and the ionized spark gap. (Some Professor of EE is welcome to comment here).

As for current limiting, many coils employ a series resistor in the primary which limits current and is shorted out during starting.

(From: Mark Kinsler (kinsler@froggy.frognet.net)).

I use a 12 volt battery and it works pretty well. Probably the best high voltage power supply for careless amateurs is the one I designed, which could be found on my Web page if I knew how to do schematics but I don't. But it's simple enough.

I've been driving my old 12 V coil (bought as a replacement for the one in my Econoline but never used) through a buzzer-type interrupter made from an old relay. I put a capacitor across the contacts for good luck, and for the most part it works pretty well. It'll give me about a 1/2" spark, which is all I need for my illegal spark transmitter and the spark plug in my famous "One Stroke Engine" demonstration. However, it yields some amusing effects, to wit: blue sparks dancing around on the battery lead and the battery itself, extremely strange noises, copious production of ozone, and the occasional puff of smoke. I have the whole mess mounted inside a plastic 2-liter cola bottle. On the advice of my friend Dewey King, who restores old gas engines from oil rigs, I've purchased a Chrysler ballast resistor to put in series with the battery and thus keep the coil healthy.

All you need to do is make a trip to the local auto junkyard:

Buy a used but fairly viable car battery, an old-fashioned ignition coil (i.e., before electronic ignition came out in the '70's), an ignition condenser (capacitor) from out of a dead distributor, and the heaviest 12 volt spdt relay you can get from Radio Shack. DPDT is okay, too.

1. Figure out how to connect the relay so it buzzes.

2. Connect the capacitor across the contacts

3. Connect the primary winding of the ignition coil in parallel with the relay coil.

If you do this right, the relay contacts will give a pulsating current through the ignition coil primary. You'll get a several hundred Hz, 12,000 V between the secondary (the central tower of the coil) and ground. It'll give you a big surprise but it won't kill you unless you're pretty determined to do yourself in.

I've found that only a car battery has sufficiently low internal resistance to run the thing: my big old bench power supply won't do it. So keep a trickle charger on the battery. It seems capable of giving a 3 cm or so arc depending on conditions.

(From: Pamela Hughes (phughes@omnilinx.net)).

I did something like that only it plugged into the wall. Don't remember the circuit but it was a 33 uF, 630 VAC mercury vapor ballast cap connected to a rectifier in a linear fashion (much like using a cap for an AC resistor only the rectifier prevented bidirectional current flow...). This was connected to an 800 V, 6 A SCR and a neon lamp for a diac in a trigger circuit. Adjusted the trigger point so the scr would fire at a certain point in the AC cycle and discharge the cap through the primary of an ignition coil. If you adjusted the trigger point right, you could get about 3" to 4" sparks. Connected that to a 40 KV TV rectifier and a cap made from a window and some aluminum foil and to a 2" spark gap. Wouldn't fire unless something was placed in the spark gap, but then it went off with a bang that would put any bug zapper to shame.

BTW, I took the ignition coil apart, disconnected the common lead connecting the primary and secondary and then used the secondary and core for a giant sense coil for monitoring changes in magnetic fields... thing would make the volt meter jump if you brought a magnet anywhere close to it, but mostly it just fluctuated with atmospheric effects like lightning.

(From: Pierre Joubert joubertp@icon.co.za)).

1. Use a monostable-based circuit which gives the maximum 'on' time for

current in the coil. As revs go up, many older systems produce reduced spark energy simply because the rate of rise of current in the coil prevents full current from being reached before the current has to be switched off.

2. Use one of the coils which is designed to operate normally with a series resistance, which is conventionally bypassed during cranking to help get a better spark on the reduced battery voltage. But instead, limit the current in the coil to a safe value by setting a current limit around the switch transistor. This prevents the coil overheating (which it would if you used it without the resistor in a conventional system.

3. Look around for the 'best' coil you can find; you might find a better match to your needs by using a coil from a different model or even make of car. If you know the R and approximate L you can model the current buildup and estimate the energy available. Generally the more energy the better, assuming that the transformation ratios of most coils are roughly the same, which was true way back when.

Mark's comments on high voltage lab conditions:

(From: Mark Kinsler (kinsler@frognet.net)).

So how do you make your high-voltage laboratory safe? Well, you just assume that anything you build is likely to catch fire and/or arc over, and design your lab space accordingly. Stay out of the way of capacitor strings, though when these blow up the shrapnel is generally pretty harmless. I've gotten stung by exploding carbon resistors, but again, it's no big deal if you're well away from them. In general, take the same precautions with high-voltage or high-current components that you would with small fireworks: avoid flammable environments and stay well away from them. If all else fails, take the stuff outside.

My advisor at Mississippi State University observed that if you never damage any equipment and you don't have fairly catastrophic failures, you're probably not doing any research. That helped justify the 6" crater I blew in the concrete lab floor (a record that still stands--his crater was only 4", though there were several of them produced at once.)

Cheap sources of magnet wire:

It has been suggested that transformers, inductors, and TV/monitor deflection coils are inexpensive or free sources of magnet wire. This may be OK for antennas or similar applications where the insulation isn't critical. However, unwinding those coils may result in damaged insulation as the wire is peeled apart since they tend to be impregnated with varnish. This makes the wire unsuitable for winding new coils. Unless, you have a way of dissolving the varnish without destroying the insulation, the risk of a random shorted turn or two (or many) buried beneath several thousand nice separate ones isn't worth it!

However, a nice source of fine magnet wire is relays and solenoids - many have very fine wire - #40 for example - and miles of it (well thousands of feet at lest). These are very often not varnished so they unwind easily (just don't let them unwind all over your junk drawer!).

Plasma globes:

A 'plasma globe' is one of those things sold at Radio Shack and gift shops which have a glass sphere containing a partial vacuum sitting on a power supply base which is a high frequency inverter. The pressure is such that the discharge tends to take place in streamers rather than as a diffuse glow. The resulting display is supposed to be neat, nifty, interesting, etc. When you place your hand(s) on the globe, the patterns of the discharge inside change.

Recent Sci-Fi movies and TV series seem to have latched onto plasma globes as high-tech replacements for the old-fashioned Jacobs Ladder :-). (E.g., certain episodes of "Star Trek the Next Generator" and "Star Trek Voyager".)

One such product is called "Eye of the Storm".

It should be possible to construct these gadgets with salvaged flyback transformers, power transistors, and a few other miscellaneous parts using a large clear light bulb - good or bad, doesn't matter - for the discharge globe (However, I don't know how good these actually are for this purpose).

Of course, purists will insist on fabricating their own globe (and official ones can also be purchased at exorbitant prices as well).

As far as I know, these will work with just regular air (though the expensive ones no doubt have fancy and very noble gasses!) and the vacuum is not that high so a refrigeration compressor should be fine.

See The Electronic Bell Jar vacuum technology articles for info on using refrigeration compressors as vacuum pumps.

However, since large clear light bulbs may also be satisfactory (though I don't which ones to recommend), there is may be no need to mess with a vacuum equipment :-). And, of course, you have a wide selection of inexpensive types to use for experiments, and dropping one or blowing it up isn't a disaster!

Excitation is usually from a high frequency flyback transformer based inverter producing 12 to 15 KV AC at around 10 kHz. Its HV terminal attaches to the internal (center) electrode of the globe or light bulb. The HV return is grounded. Ionization of the gas mixture results from the current flowing due to capacitive coupling through the glass.

For a power source, either the "Simple High Voltage Generator" or "Adjustable High Voltage Power Supply" would be suitable. See the document: "Various and Diagrams" for circuit ideas.

However, note that its output must be AC so there must not be any internal HV rectifier in the flyback transformer (which may be hard to find these days since most flybacks have internal rectifiers). (If a flyback with an internal rectifier is used, the globe will just charge up like a capacitor which is pretty boring after a few milliseconds!)

(Portions from: Steve Quest (Squest@mariner.cris.com)).

A $20 air conditioner repair hand-pump is fine. If the colors of plain air are not 'pretty' enough, let me recommend what is used in commercial units: a mixture of low pressure argon and neon. If you want to be extra fancy, try all the inert gasses, or a mixture of them all, helium, neon, argon, krypton, xenon, radon. :) Of course, radon may not be safe/legal, or even available. You could just toss a chunk of radium into the globe, it will generate the daughter isotope Rn(222) thus slowly, over time, enhance the color of the gas mixture. Just a thought.

The power supply needs to be dielectrically isolated (using the glass as the dielectric), otherwise you'd have direct emission from the metal, and it would be more of a light bulb than streaks of color. Plus, people touching it would feel a tingle while the dielectrically isolated is less likely to shock. What this means is that a direct connection to the filament lead wires is not that great as you really want glass in between the driving source the center as well as the outside globe.

* If you are making your own 'globe', one way to do this is to fuse a glass test tube into the center and coat its interior with conductive paint. This then becomes the center electrode.

* For a light bulb (which isn't really recommended anyhow), you can try to use the filament directly or cut the lead wires as close to the glass as possible and insulate them with RTV or HV putty. Then coat the remainder of the interior of the glass filament support structure with conductive paint to use as the center electrode.

If you cannot locate a suitable flyback, wind your own. Tesla-style air core transformers work.