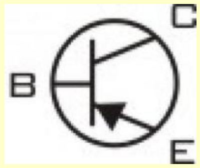
Chattanooga Amateur Radio Club P.O. Box 23121 Chattanooga TN 37422 http://w4am.org

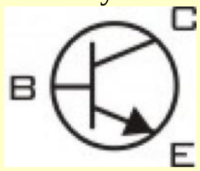
July 2010
Volume 22, Issue 07

Transistor theory

Inside a transistor



PNP symbol



NPN symbol

A transistor is made of 3 semi conductive materials connected as P-N-P for PNP transistors and N-P-N for NPN transistors. The letters P and N stands for **P**ositive and **N**egative. So, a PNP means that there is a **P**ositive-**N**egative-**P**ositive connection of materials.

We will only discuss the NPN transistors. PNP are similar in operation and theory except that they have opposite polarity and thus opposite connection and current flow.

A forward biased junction (PN for example) is compatible to a low resistance circuit element and can let flow of high current pass from it. Opposite, a reverse biased PN junction is equivalent to a high resistance circuit element and leaves very few (almost none) current to flow from it. Using Ohm's law, we have:

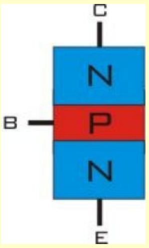
R = U / I and P = U * I =>
P = I2 * R

This means that the power developed across a high resistance element is greater than the one developed across a low resistance element. On a transistor that contains two junctions P-N and N-P (P-N-P), a low power signal could be injected into the forward biased junction and produce a high power signal at the reverse biased junction. We could consider a transistor as an amplifier of input signal.

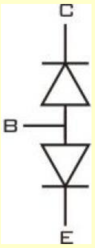
Transistor pins

Each transistor has 3 connecting points: The **base** (letter **B**), the **emitter** (letter **E**) and the **collector** (letter **C**). These points can be found in the symbol as follows: The emitter is always the pin with the arrow. The base is always the pin on the flat side of the symbol. The other pin is the collector. Also, from the symbol we can distinguish what type of transistor it is. Looking the emitter pin, when the arrow is pointing to the base of the transistor, then it is a PNP type transistor. If it points the other side, it is a NPN transistor.

How transistors operate



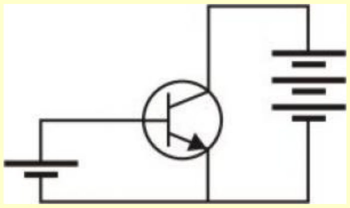
Schema 3.1
Connections of the semiconductive materials inside a NPN transistor



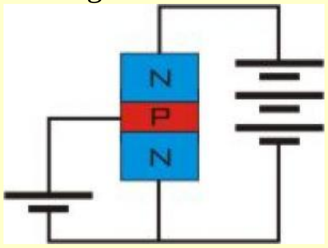
Schema 3.2
The equivalent circuit of a transistor

A NPN transistor is made as shown in the **Schema 3.1** left.

The N material comprising the two end sections of the NPN transistor contains a number of free electrons, while the P (base) section contains an excess of holes. Each junction acts just like a diode does, as seen in the equivalent circuit. A depletion region is developed and the junction barrier appears. But, as said before, the transistor is used as an amplifier. To use it like so, each of these junctions must be modified by some external bias voltage. This voltage must be forward biased on the emitter-base junction and reverse biased on the collector-base junction.



Schema 3.3
Biasing a NPN transistor

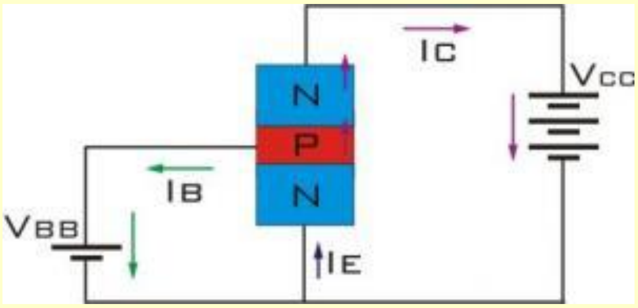


Schema 3.4
Biasing a NPN transistor

In Schema 3.3 and Schema 3.4, you can see a schematic diagram of this polarity. One technical matter when contracting the transistor is that the emitter is more heavily doped than the P material and this results in more current being carried across the junction by the majority carrier holes from the P material. Therefore, the conduction through the forward biased junction is mainly by majority carrier electrons from the emitter (N material). This is why connecting two diodes as per the equivalent circuit will not result into a transistor. We will call EB the emitter-base junction and CB the collector-base junction.

The EB junction is forward biased and this will result into electrons leave the negative terminal of the battery and enter the N material. Since electrons are majority current carries in the N material, they pass easily through the emitter, cross over the junction and combine with the holes in the P material (base). For each electron that fills a hole in the base, another electron will leave the base and enter the positive terminal of the battery. Therefore, a new hole is created in the P material.

On the other hand, the BC junction is reversed bias. Because of that, only a very few current flows from within it. This amount of current is called minority current or reverse current. This current is produced but he electron-hole pairs. The carriers for this are the electrons in the P material and the holes in the N materials (that are very few but they still exist). This minority current is the alpha and omega of the transistor operation.



Schema 3.5
A properly biased NPN transistor

The circuit in **Schema 3.5** shows a properly biased NPN transistor. The voltage on base (Vbb) is very small, maybe 1volt or less. The voltage on the collector (Vcc) is much bigger and depends from the type of the transistor. This difference is important in order to have current flow from emitter to collector.

Because of the power applied to the transistor, there is some current flowing from te emitter, the how called 'Ie' or emitter current. This current is actually the electrons in the N material of the emitter. They travel easily through N type material to the first NP junction on the base. This junction is forward biased and so electrons continue their journey to the base region. The base is P-type and thus, some electrons during their movement, they combine with the holes in the P-type material (in P-type, holes are the majority carriers and electrons become the minority carriers). As said before, for each electron combined with a hole, another electron move out the base and returns to the battery Vbb. This will cause finally the base current (Ib). But the base, during transistor construction, is a very thin layer and lightly doped. This will reduce the opportunity of electrons combine with holes. So, the biggest amount of electrons that will enter the base, will finally NOT combine with a hole, but will go under the influence of the large collector reverse bias through the P material of the base and through the N material of the collector. This happens because this bias acts as forward bias for the minority carriers in the base (electrons) and accelerates them through the BC junction onto the collector region. The electrons will then become again majority carriers (because collector is a N type material) and will easily go through the collector and return to the battery Vcc. This will cause the collector current AKA Ic.

The collector is made quite larger than the base to increase the chance of collecting carriers that diffuse to the side as well as directly across the base region and also to enable the collector to handle more current (and heat) without being damaged. As described before, the current that flows within a transistor is:

Ie= Ib + Ic, Ic >>> Ib

Actually, sometimes Ic is the 98% of the Ie and Ib is 2% of Ie!

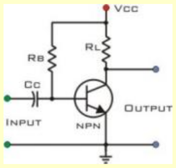
Finalizing, we can say that the emitter current is the total current within the transistor and is separated into base and collector current. Since the amount of current leaving the emitter is solely a function of the EB bias and because the collector receives the most of this current, a small change in EB bias will have a greater effect on the collector current and we could finally understand that:

A current control an a very small scale, will cause a relatively current change to the collector current but in a very larger scale.

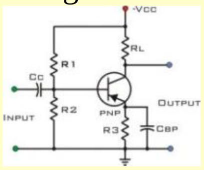
Biasing transistors

In order to have a proper operating transistor, it must be properly biased. There are various ways to bias a transistor. The most basic ways are Base-Current Bias (Fixed Bias), Self-Bias and Combination Bias.

Base-Current Bias (Fixed Bias)



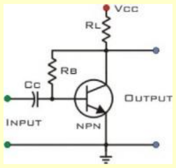
Schema 5.1
Fixed biasing a NPN transistor



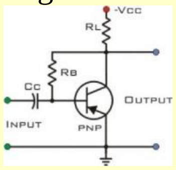
Schema 5.2
Fixed biasing a PNP transistor

In this bias method, a biasing resistor is connected between the collector supply and the base. This is a very simple arrangement but carries a heavy withdraw. It is very unstable in means of temperature changes. If the temperature of the transistor changes, either by changing of ambient temperature or from current flow within the transistor, the dc operating point (AKA quiescent or static point) will change. This change is most undesirable because it affects the amplification gain and may also result into distortion on the output signal

Self Bias



Schema 5.3
Self biasing a NPN transistor

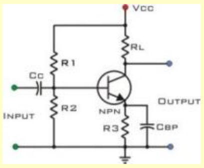


Schema 5.4
Self biasing a PNP transistor

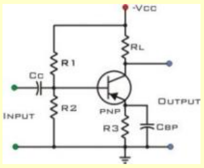
In this type of biasing, the biasing resistor is placed directly between the collector and the base of the resistor. With this biasing, feedback voltage can be fed from the collector to the base to develop forward bias. This is a better connection because if temperature increases and cause an increase in collector current, the collector voltage will fall because of the increase of voltage produced across the load resistor RL. This drop in VC will be fed back to the base and will result in a decrease in the base current. The decrease in base current will oppose the original increase in collector current and tend to stabilize it. The exact opposite effect is produced when the collector current decreases.

The temperature change with this way will be managed as long as it is a moderate ambient temperature change. It cannot handle large temperature changes. Also, because the signal on the collector affects the base voltage and because they have 180 degrees phase difference, the amplification is slightly reduced. This is also known as "negative feedback", sometimes useful to prevent output signal distortion and self bias may be used for this purpose.

Combination Bias



Schema 5.5
Combination biasing a NPN transistor



Schema 5.6
Combination biasing a PNP transistor

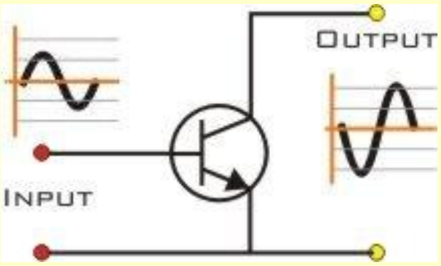
This type of transistor biasing is a combination of fixed and self bias. Using this way, the stability of the operation of the transistor is improved and also the disadvantages of the other methods are overcome.

The fixed bias is implemented using the voltage divider R1-R2. The current flowing through the voltage divider network biases the base positive with respect to the emitter. Furthermore, the voltage divider tend to keep the base bias steady while the emitter bias changes with emitter conduction.

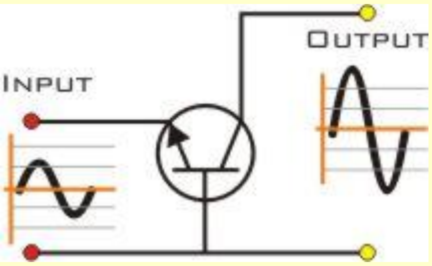
The self bias is implemented using the resistor R3 connected in series with the emitter. If Ie increases, the voltage drop across R3 will also increase and thus the Vc will be reduced. A drawback is that again the amplification is slightly reduced, but the stability is dramatically increased. To provide further more thermal stability and allow minimal signal degeneration, a bypass capacitor Cbp is places parallel to R3. Cbp is large so rapid signal variations will not change its charge materially and no degeneration of the signal will occur.

Connecting transistors

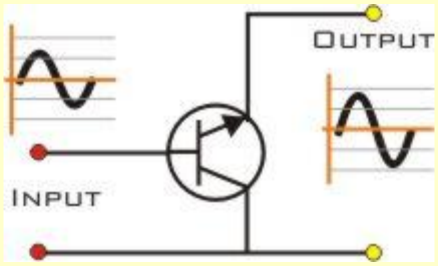
There are three ways that a transistor can be connected in a circuit: Common emitter, common base and common collector. These three types are shown below:



Schema 5.1
Common Emitter transistor connection



Schema 5.2
Common Base transistor connection



Schema 5.3
Common Collector transistor connection

(In our examples we use NPN transistors to demonstrate but it is the same as using PNP transistors, with opposite power supply)

Each type of connection has different characteristics.

Common Emitter connection (CE)

This is the most common connection type when used for amplification circuits. It can provide quite a good voltage, current and power gain. It also has a low input resistance (500 to 1500 ohms).

In this type of configuration, the input signal is applied between the base and the emitter, a low resistance and low current circuit. When the input signal goes to positive values, so does the base to go to positive values, decreasing the forward bias which reduces the corrector current and increases the collector voltage. The collector current that flows through the high resistance reversed bias junction also flows through a high resistance load resulting a high level of amplification.

The output signal goes negative when the input signal goes positive. The two signals have 180 degrees phase difference. This happens only in the common emitter configuration.

The amplification amount is called Gain. It is the ratio of the output versus the input. Each transistor configuration gives a different value of gain even though the same transistor is used. The selection of configuration to be selected is subject to the type of application. The current gain in the common emitter connection type is so called "BETA" from the Greek letter β. Beta is the relationship of collector current to base current. Can be calculated by:

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

Δ comes from the Greek letter **DELTA** and indicates a very small change. You may also see **β** with the term $\mathbf{h_{FE}}$. The $\mathbf{h_{FE}}$ and **β** are the same.

The **resistance gain** of the common emitter can be found in a method similar to the one used for finding beta:

$$R = \frac{Rout}{Rin}$$

The **voltage gain** is calculated by the form:

$$E = \beta \times R$$

And the **power gain**:

$$P = \beta \times E$$

Common Base connection (CB)

This type of connection is mainly used for impedance matching, since it has a low input resistance (30 ohms-160 ohms) and a high output resistance (250 kilohms-550 Kohms). But because of this low input resistance and because of the low current amplification (less than 1), this type is not so often used. Microphone amplifiers may use this kind of transistor connection.

In the common-base configuration, the input signal is applied to the emitter, the output is taken from the collector, and the base is the element common to both input and output. Since the input is applied to the emitter, it causes the emitter-base junction to react in the same manner as it did in the common-emitter circuit. For example, an input that aids the bias will increase transistor current, and one that opposes the bias will decrease transistor current.

The input and output signal are in same phase. This means that when the input voltage rises, so does the output voltage.

In this type of connection, the **current gain** is named with the letter **ALPHA** (from greek letter **α**) and it is:

$$\alpha = \frac{\Delta I_C}{\Delta I_E}$$

It can be seen that, because of Ic being always less than Ie the current gain in this type of connection is always less than 1. **α** can also be found as $\mathbf{h_{FB}}$. $\mathbf{h_{FB}}$ and **α** are the same. Given **β**, you can find **α** by:

$$\alpha = \frac{\beta}{\beta+1}$$

You can calculate the resistor, the voltage and the power gain from the same forms as did before for the common emitter connection.

Common Collector connection (CC)

This type of transistor is mostly used for impedance matching. It is also used as a current driver, because of its substantial current gain. It is particularly useful in switching circuitry, since it has the ability to pass signals in either direction (bilateral operation).

The input resistance for the common collector ranges from 2 kilohms to 500 kilohms, and the output resistance varies from 50 ohms to 1500 ohms. The current gain is higher than that in the common emitter, but it has a lower power gain than either the common base or common emitter. Like the common base, the output signal from the common collector is in phase with the input signal.

For the common collector **current gain**, we use the Greek letter **γ** (**GAMMA**). The form of calculation is:

$$\gamma = \frac{\Delta I_E}{\Delta I_B}$$

Knowing **β** of **a** transistor, you can calculate **γ** by:

$$\gamma = \beta + 1$$

And to make the things more complete, knowing **α** you can calculate **β** by:

$$\beta = \frac{\alpha}{\alpha - 1}$$

Using the same formulas like in case of common emitter, you can calculate easily the resistance, voltage and power gain for this type of connection
Summarizing

Below is a table that will help you to choose the best connection type for your application.

	Common emitter	Common base	Common collector
I/O Phase difference	180°	0°	0°
Input resistance	MEDIUM	LOW	HIGH
Output resistance	MEDIUM	HIGH	LOW
Current gain	MEDIUM	LOW	HIGH
Voltage gain	MEDIUM	HIGH	LOW
Power gain	HIGH	LOW	MEDIUM

ARRL Files Comments with FCC Regarding Spread Spectrum Issues

In response to a 2006 ARRL *Petition* regarding spread spectrum issues, the FCC released a *Notice of Proposed Rule Making* (*NPRM*) on March 16 (WT Docket No 10-62), proposing to amend Part 97 to facilitate the use of spread spectrum communications technologies by eliminating the requirement that amateur stations use automatic power control (APC) to reduce transmitter power when the station transmits a spread spectrum (SS) emission and reducing the maximum transmitter power output when transmitting a SS emission. The ARRL filed comments on this matter on June 14, 2010.

In its comments, the ARRL requests that the FCC proceed with the following proposals in the *NPRM*:

- To delete the APC requirement of Section 97.311(d) of the Commission's rules.
- To move the power limit for SS communications from Section 97.311 to 97.313(j) of the rules.
- If the record developed in comments in response to the *NPRM* supports the proposed power reduction from 100 W PEP output power to 10 W, as proposed, then to implement that power reduction, subject to revisiting the matter at a later date if the reduction proves a substantial disincentive to expanded SS experimentation in the Amateur Service.

The ARRL's 2006 *Petition* proposed the deletion of Section 97.311(d) of the Commission's rules, save for the first sentence thereof. "The effect of this would be to eliminate an automatic power control provision for Amateur Radio SS communications," the ARRL stated in its comments. "The *NPRM* proposes that relief, but at the same time, as something of a tradeoff, proposes to reduce the maximum transmitter power output when an amateur station is transmitting an SS emission, from a maximum of 100 W to a maximum of 10 W PEP transmitter output power."

The ARRL maintains that proposed deletion of the APC requirement for amateur SS communications is timely and necessary, stating that the ARRL's *Petition* showed that the APC requirement has, since it was first imposed in 1997, "been impractical of compliance; unnecessary in order to protect other Amateur Radio operations or the operation of any licensed radio service sharing certain Amateur Radio allocations; and it has served as an unintended, but effective deterrent to Spread Spectrum experimentation in the Amateur Service."

Pointing out that the FCC has revisited the rules governing amateur SS communications several times, the ARRL notes that to its knowledge since the first SS operation was authorized by the Commission, "has anyone provided documentation of harmful interference from Amateur SS communications to narrowband amateur operation, nor to any authorized radio service operating in the same spectrum. Neither, as far as ARRL is aware, has there ever been an allegation of actual interference to any Part 15 device or system operating at 902-928 MHz or 2400-2450 MHz from an Amateur SS system."

In 1995, the ARRL proposed changes to the SS rules, including was a suggestion to incorporate APC for SS communications. Previously, the SS rules [then Section 97.311(g)] simply limited stations using SS emissions to 100 W. "It was believed at the time that APC would be a technical implementation of the fundamental, overarching requirement in the Amateur Rules that at all times an amateur station must use the minimum transmitter power necessary to carry out the desired communication," the League stated in its comments. "The ARRL believed at the time that APC for SS could be accomplished technically. It was not, however, ever suggested by ARRL or the Commission that APC was necessary to avoid interference. Quite the contrary; the Commission concluded that SS communications were entirely compatible with other operations on the same frequencies."

The ARRL maintains that the Commission should avoid the imposition of an effectively arbitrary power limit while eliminating the APC requirement, saying that doing so "is arguably substituting one disincentive to SS experimentation with a different one. Such would be antithetical to the goal enunciated by the Commission in the *Notice*, which is to 'encourage individuals who can contribute to the advancement of the radio art to more fully utilize SS technologies in experimentation.' Nor is a power reduction necessarily the 'balance' of interests of users in mixed-mode and mixed-service frequency bands 'until sharing protocols are sufficiently developed to avoid interference' as the Commission describes the power restriction. No balancing has been shown in 25 years of SS operation to be necessary."

That said, ARRL told the FCC that it is not presently prepared to argue that a power limit of 10 W PEP output is a substantial handicap to SS experimentation: "While the proposed 90 percent decrease in maximum power output is not viewed as necessary, ARRL is willing to accept the restriction presently, subject to revisiting the matter after some reasonable experience is gained with it. The Amateur Service can, in the meantime, ascertain (1) whether or not the reduced power limit is or is not a substantial disincentive to expanded SS experimentation, and (2) whether or not increased power can be implemented without a risk of additional interference to other amateur stations and other radio services in the bands in which SS is and will be deployed."

Chattanooga Amateur Radio Club
June 3, 2010 Monthly Meeting

Officers Present: Mark Rose, Rick Curtis, Jim Knight, Susan Miller, Jim Bowman
Directors Present: Tom Cash, Susan Miller, Bill Dobbs, tom Morgan, Tom Wolfe, Lowell Bennington, Ben Timmerman

Meeting was called to order at 7:00.
Greetings to visitors Eryndlia Mavoureen, KK1T, Danelia and D.J. Chappell.
Introduction and voting on two new members: Charles White , KJ4TVL, a new tech; and David Cox ,WJ4MUU. Both were accepted. Let's make them welcome.

Motion was made to accept last month's minutes as written in the WAVES. Motion was seconded , motion passed.

Treasurer's report was given by Jim Knight.

Hamfest account	9604.07
Club checking	9503.91
Total	$19,107.98

61 repeater is back on the air, 39 repeater giving trouble

We need volunteers to help finish up the radio room at the Red Cross Bldg. The room is looking really nice. Radio equipment is engraved with W4AM to ID the club's equipment.

Field Day non chairmen Tom Wolfe and Jim Knight have selected captains (or non captains?) Bill Dobbs for 15 and 40 station. Mark Rose for 20 station. If you would like to operate please contact a captain for a time slot. They are rapidly filling up.
Field Day is June 26 at River Park. The club may set up a "go to" station if enough people show up. The tents will be set up. Sandwich fixings for lunches. Several fast food restaurants are near.

There was a discussion on setting up for the Boy Scouts JOTA (Jamboree On The Air) October 16-17.
Also looking at having volunteers teach the scouts for 1 hour a day for a week at possibly Skymont. Suggestion was made to get a committee together to do this for next years event. Also possibly have something like this at Hamfest this year.

Reminder that VE testing is the first Friday of each month at the Red Cross Bld.

Hamfest Chairman, Jim Bowman, announced the Hamfest will be held at the East Ridge Civic Center. .
He has sent emails to all the vendors and had two takers so far. He has printed up fliers. If you are going to a Hamfest anywhere, please get some fliers and take with you .
Ben is going to get a page for Hamfest on the website along with a Google map.

Rick Curtis gave an informative program .
Meeting was adjourned @ 9:00
Next monthly meeting will be August 5 @ 7:00 , Red Cross Bldg, McCallie Avenue.
The Board will meet on June 16 and July 21, at Ryan's on Hixson Pike. If you have any business for the board, please contact an officer or director.

See you at Field Day!!!
Be Safe!

Respectfully submitted,
V. Susan Miller, KI4RZJ
Recording Secretary

FCC Seeks Comments on Amateur 5 MHz (60 Meters) Allocation

In May, the FCC released a *Notice of Proposed Rulemaking* (*NPRM*) -- ET Docket No 10-98 -- proposing to amend the Part 97 rules governing the Amateur Radio Service. Specifically, the Commission looks to modify the rules pertaining to the use of five channels in the 5330.6–5406.4 kHz band (60 meters) to replace one designated channel with one that is less encumbered, to authorize three additional emission designators and to increase the maximum authorized power in this band. On June 15, a summary of the *NPRM* was published in the *Federal Register* and the FCC is seeking comments on it. Comments must be filed on or before July 15, 2010 (30 days after publication in the *Federal Register*); reply comments must be filed on or before July 30, 2010 (45 days after publication in the *Federal Register*). Instructions on how to file comments are listed beginning on page 6 of the *NPRM*.

Hamfest Chattanooga 2010

Saturday, October 23, 2010

East Ridge Community Center, 1517 Tombras Ave., East Ridge, TN 37412
Lat: 34°59'42.00" N Lon: 85°14'33.00" W

8:00 A.M. to 2:00 P.M. (E.D.S.T.) VE Testing at 10:30 A.M.

Free Admission Free Parking

All Indoor Tables $5.00 All Bone-Yard Spaces $5.00

All Areas Are Handicapped Accessible

Coffee and Breakfast Items Available on Site

Talk-in: 146.790- (no tone)

Vendors contact Jim Bowman, W4DFS@arrl.net or 423-394-7373
for preferred table space

This is an ARRL sanctioned event.

Visit http://w4am.org for updates

- From the West on I-24E (Nashville, Birmingham, Huntsville)

Travel I-24 East to Exit #183. At bottom of exit ramp turn right at traffic light (Germantown Rd). Travel approximately 1 mile to traffic light and turn left on Ringgold Rd. (Hwy. 41S). Travel East to traffic light #8. Turn right on Tombras Ave. and follow signs to parking.

- From the North on I-75S (Knoxville)

Travel I-75 South to Exit #1(East Ridge). At the top of the ramp turn right (West) on Ringgold Rd. (Hwy. 41N) and travel to traffic light #8. Turn left on Tombras Ave. and follow signs to parking.

- From the South on I-75N (Atlanta)

Travel I-75 North to Exit #1B (East Ridge). At the top of the ramp continue West on Ringgold Rd. (Hwy. 41N) and travel to traffic light #8. Turn left on Tombras Ave. and follow signs to parking.

The hamfest is located at the East Ridge Community Center, **not** Camp Jordan.