TIMBER FRAMING

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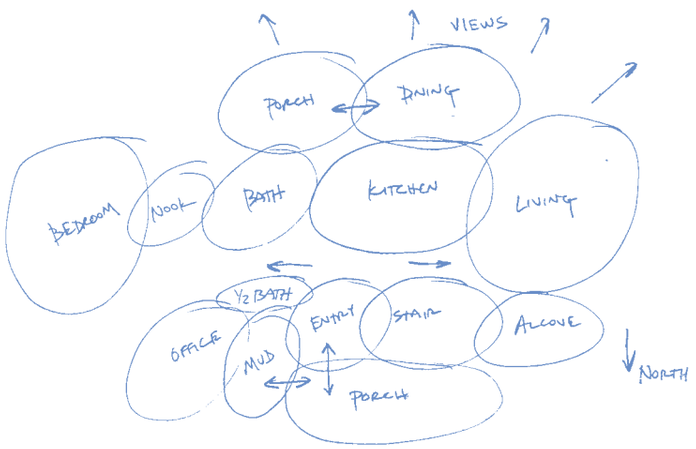
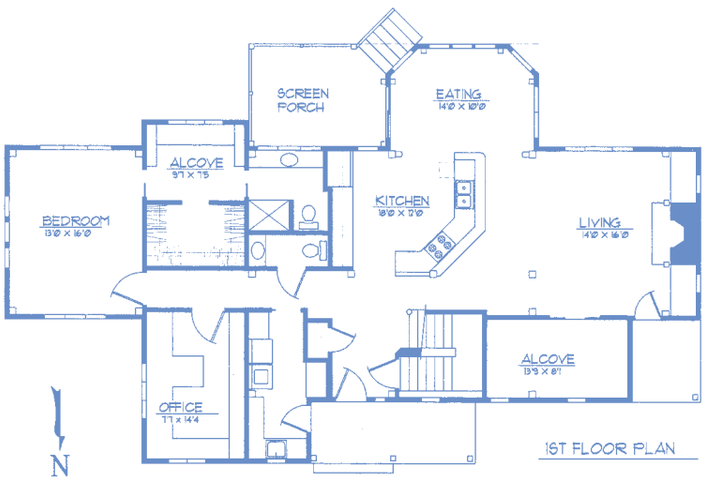




Factors in Timber Frame Design

Kicking Horse Bridge

TIMBER FRAMING FOR BEGINNERS

II. Ten Factors in Timber Frame Design

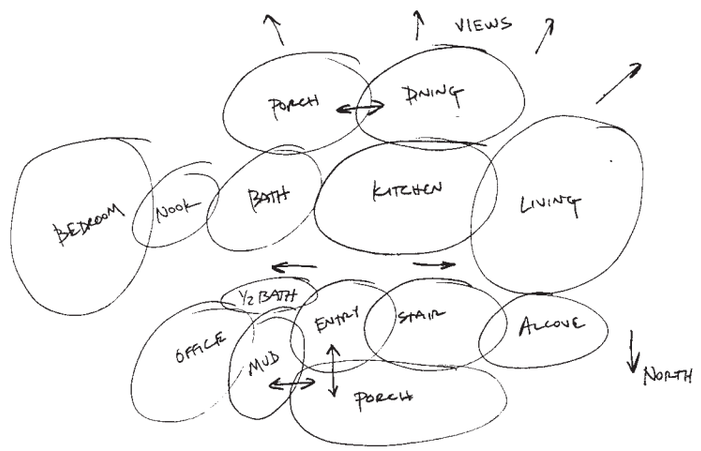
ONE of the appeals of light framing is its adaptability. Almost any house could be stick framed. Frequently enough, framing plans aren't even included with architectural drawings, since the framing skills required are so ubiquitous and standardized. But once you have decided that you want a timber frame, you must consider some extra parameters as early as possible in the design.

A frame for a small, simple house or barn is relatively easy to design. I break down the process into *architectural* design, which determines where posts, beams and braces go according to space planning concepts and aesthetics, and *engineering* design, which determines the joinery and sizes of timber required to carry the loads involved. It's always a good idea to get the advice of professional designers, especially if you have any doubts about your project, but by doing some of the preliminary work yourself you can save yourself some consultation time and money. Here are ten factors that should help you through to an initial design.

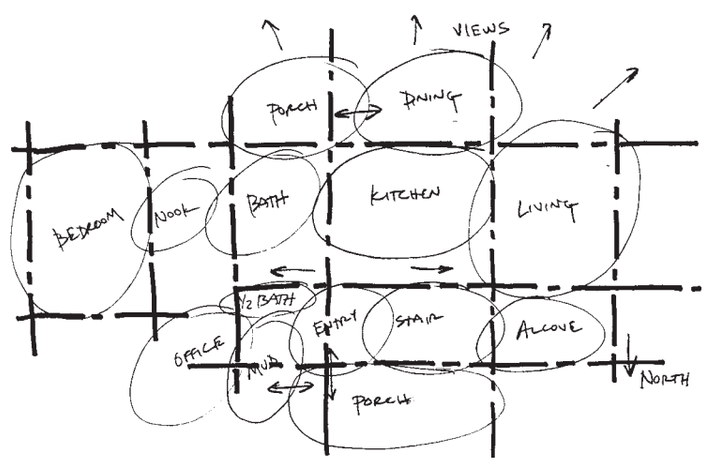
1. The Floor Plan. Most drawing starts with the floor plan, derived by applying a *structural grid* to the bubble diagrams (example at right) of spaces and the program the designer or client has probably wrestled with for a time. Because the timber frame is such a grid, it's important not to wait too long to consider where the frame components will go. It's also difficult, though sometimes possible with simple plans, to take a finished set of drawings for a stick-framed house and fit a timber frame in.

The most economical house to build has only four corners—a rectangle. Every time you add corners you add significant complexity and therefore cost. When first designing a timber frame for a house, I'm usually faced with an arrangement of amorphous shapes (the bubble diagram) showing the activities in the house and their relationships to one other. I also have a rough idea of the space required for each activity. The *plan,* apparently an overhead (birds-eye) view, is properly a horizontal section or slice through the building at a 5-ft. height above the floor level. In drafting, most changes and decisions are based on the activities served by the first-floor plan; the foundation, other floor plans and even the elevations are derived from this first drawing. Try to get most of the things right on the first floor (which I assume will contain the principal living areas) before moving on to the other floors. Don't forget storage areas. And give sufficient attention to the stairs, which I think are the hardest thing to design well in a house.

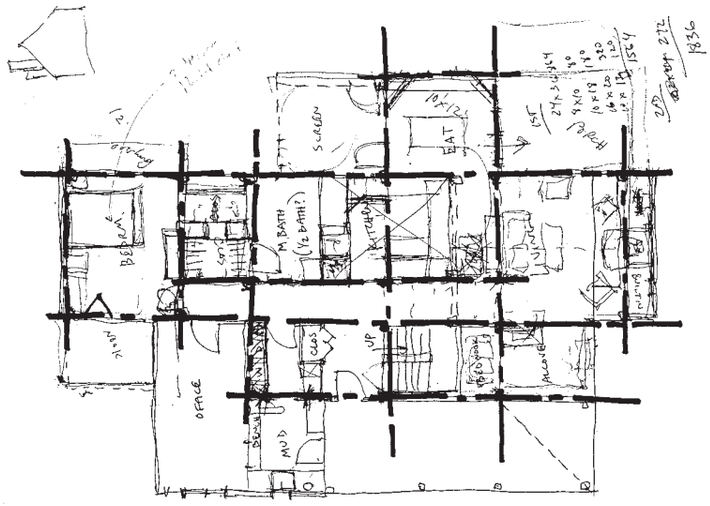
I start by assuming a 12-ft. grid of posts in the first-floor plan. Girders (beams that carry joists) rest on the posts, and 12 ft. is an easy span for most joists and girders without getting into excessively large sizes and special joinery. Shorter spans are okay, but for longer ones, once they get up around 16 ft., the necessary beams get really big, and floors get bouncy. If your posts can line up in rows across both the length and width of the building, that's a good sign that you'll be able to use simple joinery and a straightforward arrangement of joists and beams above. Posts that run continuously all the way up to the roof framing (plates, purlins and sometimes a ridge) avoid unequal shrinkage in the floors that must arise if you frame the building with some posts interrupted by beams. With continuous posts (photo overleaf), their locations on the second floor are of course already determined, as are the supports in the foundation system. This is not a hard-and-fast rule; posts don't have to be supported directly underneath. They can land out on the unsupported span of a beam (*point loading),* but this should be done only with good reason and proper structural analysis.

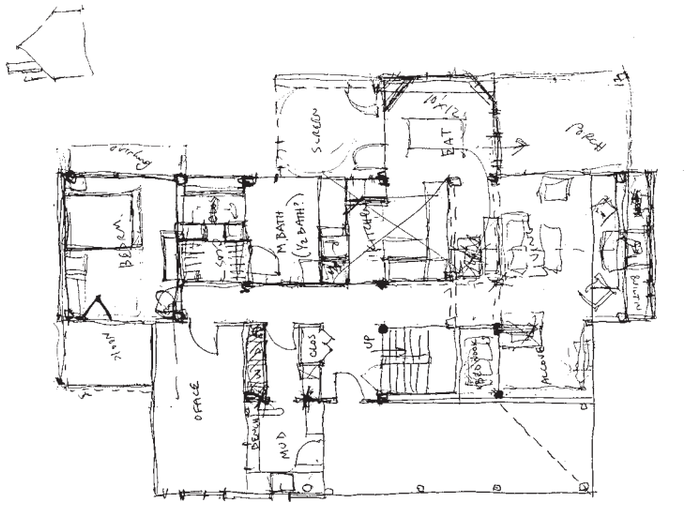


Andrea Warchaizer



Bubble diagram of program for house for family of four, with initial structural grid applied. Drawing sequence continues overleaf.





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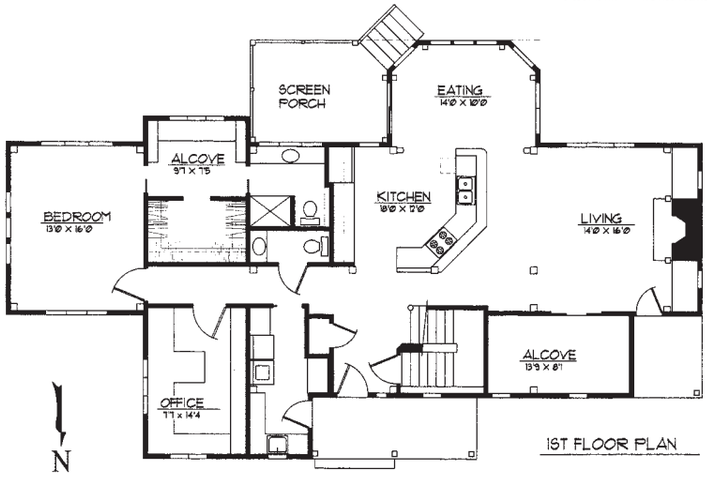

Sequence of designer Andrea Warchaizer's drawings for a timber-framed residence in Lexington, Virginia, completed earlier this year.

Timbercraft Homes

Continuous, full-height posts avoid differential shrinkage at floors.

Christopher Alexander (in *A Pattern Language*) names one pattern Varying Ceiling Heights, which distinguishes different areas on the same floor level. Timber framing does this not only through various depths of joists and beams, but also the direction in which they run. It's usually most economical to run joists across the shortest span between beams, but it's not taboo to change joist direction for a desired visual effect. Designing floors and ceilings at different levels also avoids joinery concentrated at the same elevation on posts, which can weaken them.

Braces should also be considered when laying out the floor plan, since windows, stairs, passageways and traffic patterns will be decided at this step as well. Consider where people might collide with a brace while walking underneath, or where braces would interfere with windows or doors or their casings. The more braces, the stiffer the frame; at a minimum there should be at least one

Charles Landau

Four posts define the borders of a sitting area focused on the fireplace. Braces are omitted on the sides where people are likely to pass.

Post locations are also used to delineate separate activities and areas in the building. Since there are no bearing walls, partitions can be put anywhere, but one of the advantages of a timber frame is that it provides an open floor plan. You can use the posts to break up this open space by framing architectural features such as fireplaces, sitting and dining areas or staircases, as in the photo at right. Traffic flow patterns generally should not be interrupted by posts and braces, but, conversely, the latter can be used to create alcoves. going in each direction in each bent and bay line of posts. Braces work mainly in compression, so one of the two would always be working under a wind or other side load on the structure. The longer the brace, the better as well, with a 30-in. leg (in the right triangle of which the brace forms the hypotenuse) as a minimum, in my opinion. Shorter braces can actually be destructive by acting as fulcrums to drive apart the corner joints they are meant to stabilize.

Last, don't forget to check your local building code and with the

inspector about requirements such as minimum room sizes, stair header height, window sizes and heights off the floor. and the distance beams can project below minimum ceiling height.

2. Architectural Style. Design is not a linear process. You should consider all of the factors simultaneously for best results. The *elevations*, or views of the upright walls, will be determined by spatial requirements (room sizes, need for a second floor and the like) but also by the *style* of building you want. Don't get hooked on one style too soon, but be aware that one tends to build like the neighbors. For good neighborly relations you may not want to put a geodesic dome in with a bunch of Colonials. Historical precedents can be good models; here in New England we have some traditional forms such as Capes and saltboxes that suit well to timber framing. On the West Coast, the Arts and Crafts Movement might influence you. For a given square footage, multi-story houses are easier to heat in cold climates and require less foundation length; on the other hand, most houses in the south are one story and easier to maintain.

The roof is usually the dominant visual element on the exterior and does the most to state the architectural style. To help you decide roof pitch, consider your snow load and roofing labor and costs, as well as usable space you may need underneath the rafters. Valleys and hips add visual interest to the roof, and dormers may help the interior layout as well, but all increase the complexity of the framing and the potential for leaks. "Overframing" such interruptions with dimension lumber or structural insulated panels (SIPs) can simplify the work here.

Check your building code again and local ordinances for things such as maximum building height, minimum and maximum roof pitch and, in some places, architectural style controls. Again, before tackling the more complex roof systems, keep it simple until you have some experience. Consult books such as the *Field Guide to American Houses* to find guidance on your favorite style.

Jim Buck

The modern mobile crane offers the possibility of raising very large assemblies that are difficult or impossible to put together in the air.

3. Raising Method. I distinctly remember watching the design of roof frames change in the course of just a year or two, as evidenced by successive slide presentations at the Guild's annual conferences. All of a sudden we were seeing flying purlin systems (as well as floor framing), pre-assembled on the ground with soffit or tusk tenons, replacing with more load-efficient connections the drop-in joinery so common before. We were seeing an improvement in timber frame design resulting not only from a better understanding of the structure but also from an increased awareness of the capabilities of cranes at the raising.

Photos Spike Baker

Above, superior mortise and tenon joinery can be used without difficulty in floor systems if a crane does the lifting of the assembly. At right, a ladder of drop-in purlins flying in to a principal rafter-common purlin roof. Here the crane has already lifted into place the extremely heavy bents complete with rafter framing.

Will Beemer

Many hands make light work and gather people together in satisfying common effort. Hand raisings are generally quieter, too.

Crane raisings are safer and often quicker than hand raisings, and require fewer people. There are times when a hand raising is a good alternative, such as when you can't get a crane in to the site or when you want the community involved. Principal rafter systems with common purlins lend themselves to crane use, indeed almost require it, since the bents are assembled horizontally, all the way to the rafter peak, and stacked on top of one another ready for hoisting on raising day. The common purlins are then flown in individually or in strings. Hand raisings require smaller bents with lower centers of gravity, and smaller pieces to be handed up from

below. Common rafters work well here as they can be installed vertically, using gravity to secure the seat and keep the rafter from slipping down. Large-section common purlins would have to be muscled up the roof, fighting gravity all the way.

There may be times you have to design the frame to go up one story at a time, either when you don't have a crane or other means to lift bents or large pieces high enough, or because your post material will not be long enough to reach the roof beams. This would be analogous to *platform framing* in light construction. In this case you should design the frame to account for the various shrinkage rates of beams and make it uniform throughout the structure. If your posts don't line up in rows across the short dimension of the building (the way bents usually run), or if your frame design is based on the English tying joint, it may make more sense to raise assemblies that run the long direction (walls).

Before you get too far along in the design I recommend you write out, or at least imagine, a raising script, and certainly you should write out the script before the raising and distribute it to the crew. I've seen more than a few frames that were impossible to assemble without some joinery "modifications" at the site, often resulting in sawn-off tenons. Visualize how you're going to peg joints together before and during the raising; often pegs will interfere with other joinery and timbers. The more complex the frame, the more likely most of it will have to be pre-assembled on the deck and raised with a crane.

4. Structural Engineering. One of the main things building inspectors look for is the proper sizing of joists, beams and rafters. To size members, the designer must match the *loads* involved with the strength characteristics of the *species* of wood and the *width, depth, span,* and *on-center spacing* of the timber. All of these are variables the designer can play with until the requirements are met. In conventional construction, the standardization of the available sizes and grades of lumber limit these variables. In timber framing, the possibilities are much more open. And when thinking about loads, don't forget to consider the posts, whose net section—and thus load-bearing capacity—can be much reduced by joinery.

In some locales, especially those with stringent earthquake codes such as the West Coast, building inspectors may ignore the contribution of diagonal bracing to the frame's rigidity. You may be required to use SIPs, plywood or some other shear diaphragm to add to the rigidity of the frame. Inspectors may also restrict the notching of beams, sometimes allowing no cutting into the top surface. It's best to find out early if you'll be required to have your frame engineered, and then find a timber engineer who is licensed to work in your area.

5. The Wood. Strength isn't the only thing that determines the species of wood you are able to use for your frame. I'm an advocate of using local materials wherever possible, but I'll import a few pieces of Douglas fir if it saves me from using a much bigger dimension of our local Eastern white pine, or from using scarf joinery. Long continuous pieces will usually be stronger than scarfed ones, especially for plates and tie beams. If long pieces are available and affordable, deliverable and raiseable, design the frame around them. One problem with the popular principal rafter-common purlin system is the lack of continuous pieces in the longitudinal direction of the frame. Whatever the roof framing above them, continuous plates offer inherent stability, especially during the raising.

Mixing species in a frame is also okay in my book, matching the strength characteristics with the job to be performed. This is important if your woodlot has mixed species, with no one species plentiful enough for a whole frame. Species weaker in bending might serve as posts or braces, while stronger ones can be used for joists, beams and rafters. It's always nice to incorporate at least one piece of wood from the site into the frame, and, if the entire timber supply is milled or hewn onsite, it may never even have to move into a shop. Such a scenario might lend itself to a scribed frame, much as the English do, with layout occurring *in situ*. The girth and height of the trees simply determine the milled sizes of timbers available.

Other characteristics, such as rate of shrinkage and strength in shear, determine the location and dimensions of joinery and the allocation and orientation of the timber in the frame.

6. Interior aesthetics. We're attracted to timber frames because we like the look of wood on the interior. It can be overdone, however. Wood absorbs light, and wood planking on the ceiling can make an interior darker than if plaster or another light-colored surface is applied between the joists and rafters. The colors of wood can influence the choice of everything from flooring to cabinets. Species like red oak and fir have a rich reddish color, while pine has a much lighter yellowish hue (although it must be said that time softens all contrasts), and some thought should be given to how the colors of other woodwork in a house fit with the colors of the frame.

The joinery represents the craftsmanship we want to show, and should be chosen and cut to minimize unsightly gaps that could result from shrinkage. Because of differential shrinkage and distortion, and even seasonal changes once a frame is older, flush surfaces and edges are almost impossible to maintain. Joists are often shallower than the beams they go into (and occasionally even laid flatwise), not only for structural reasons but also to provide contrast and scale in the frame members. Splines and pegs are often left proud of the surface of a beam (overleaf). A contrasting color of pegs can be used to accentuate the joinery.

7. Enclosure Systems. Structural insulated panels, made of sheet goods on a 4-ft. module, have contributed much to the viability of timber framing, and also influence frame design. Since they can be put on the roof either way, a purlin or common rafter system on 4-ft. centers can be designed to conceal the panel joints. Similarly, exterior wall girts and posts can be laid out to align with seams. Wall panels usually rest either on the sill plate or the floor deck, and if the frame is moved in from the perimeter to account for the panel thickness, you should be sure that there's still adequate bearing for the posts on the foundation. A good resource for foundation details is Tedd Benson's *The Timber Frame Home*. For panel details, get an installation guide from one of the manufacturers; Winter Panel publishes a great one. No matter which supplier you use, ask early for frame-design guidelines to efficient use of their panels. Avoiding waste is a primary concern, and pre-cutting panels at the factory is worth the extra cost. Alternative enclosure systems (exterior stud walls, straw bale, straw-clay) may cost less in materials but more in labor. The requirement they have in common with SIPs is that the frame should be moved inside the enclosure system so it's completely protected from the elements. Placing the frame inside the heated space leads to the extended life span of the structure.

8. Other Systems. Mechanical systems, especially plumbing and heating, need to be considered early in the design so as not to interfere with the timber frame. Make sure you include your plumbing, electrical and HVAC contractors as soon as you can. Light-frame studs and joists can be notched for pipes, ducts and wires following code guidelines, but also rely on their close repetitive spacing to compensate. Heavy timbers are much more sensitive to notching and can be challenging to a laborer who may not realize that the timbers will remain exposed. Plumbing traps and waste and vent lines often run in walls and between floor joists, and long horizontal runs cause more problems than vertical ones. Hence, as in any house, it makes sense to stack your second-floor bathrooms over

Will Beemer

Spline joinery is popular, especially for connections in Douglas fir (as shown here), a species famously weak in tension perpendicular to the grain, the mode in which a mortise is stressed during withdrawal of a pegged tenon. Here splines are used decoratively and pegs are left proud.

those on the first floor, and if possible the kitchen, so the large pipes can run up a plumbing (wet) wall between rooms. To avoid seeing traps and runs between ceiling joists, you must have either a dropped ceiling in that area or the fixtures raised onto platforms in the room above. It's also possible to build a light-framed floor using shallow joists *over* the timber frame to provide chases for mechanical runs, or to avoid timbers entirely in the bathroom floor, in favor of light joists. We use a lot of hot water baseboard heat in our neck of the woods, and I've learned to provide a notch at the back of exterior posts at floor level for the pipes to run.

While electrical wires can be run in SIPs without problems, you should anticipate where wires on the interior might have to run over timbers, and prepare channels to hide them. The lack of interior stud walls is a disadvantage here, as there's no place to run wires vertically or to mount receptacles and switches. Consider carefully the layout of posts and beams as they relate to likely activities and furniture arrangements. Lighting can be especially problematic in large open spaces.

9. Joinery and Cutting Methods. The design of your joinery and the frame itself will reflect the tools you have to cut it. Spline joinery increased in popularity once efficient power tools became available to cut long mortises. Splines also allow you to use shorter timbers, tension joinery and three-way (photo above) or four-way connections of beams at the same level on a post.

If you're hewing timbers on the site, you'll probably want to minimize the work by leaving the timbers close to the size of the original tree, even tapered. Perhaps only one side of a log would be flattened in the case of a first-floor joist, though don't forget to strip the bark and so deprive insects of comfortable long-term shelter.

Budget. One factor that obviously affects the frame design is your budget, and cheaper almost always means simpler. Besides the complexity of floor plan and joinery, other things that may be limited or made impossible by their cost are the finishing details such as chamfering of edges and surface planing and coating.

The cost of materials is easy to estimate; labor is the hard thing to guess at. If you're new to the trade, I advise following the KISS principle: Keep It Simple and Small. Learn your capabilities and that of your crew and how big a job you can handle with the tools that you have. Study the problems and opportunities in timber framing that make it different from other systems.

Timber framing is more expensive than light framing largely because of the more highly skilled labor required. Once a client opts for the timber frame, it's not long before the entire project cost escalates as an attempt is made to match the quality of the other systems to the framing. Some people save money by building a *hybrid* frame, where the private, enclosed areas of the house are light framed while the open, public areas are timber framed. While lacking the integrity of a full timber frame, hybrids can also be built using a timber-framed first floor only, or by connecting a timber-framed interior to a conventionally framed exterior.

Because of their special characteristics, most timber-framed structures are custom designed. It's very difficult to find a stock set of timber frame plans to buy because so much depends on variable materials and methods. The final product will reflect not only your skill as a carpenter but also as a designer. —Will Beemer

Will Beemer (will@tfguild.org) has charge of the Guild's workshop program and has directed The Heartwood School for many years. This article is second in a series.

Some works on design, available from timber frame book specialists Summer Beam Books, 877-272-1987 or www.summerbeam.com:

Tedd Benson, *The Timber Frame Home*, Taunton Press, Newtown, Ct., 1988. Best overall book on architectural design for timber frames.

Jack Sobon, *Build a Classic Timber Framed House*, Garden Way, Pownal, Vt., 1993. Great book on traditional design and timber layout and cutting; good structural design section.

Christopher Alexander, Sara Ishikawa and Murray Silverstein, with Max Jacobson, Ingrid Fiksdahl-King and Shlomo Angel, *A Pattern Language*, Oxford University Press, New York, 1977. A very useful design tool for the preliminary stages.

Virginia and Lee McAllester, *A Field Guide to American Houses*, Alfred A. Knopf, New York, 1988. An encyclopedia of design patterns that give the house its distinct style.

Steve Chappell, *A Timber Framer's Workshop*, Fox Maple Press, Brownfield, Me., 1995. Good structural section and joinery details.

Fine Homebuilding Magazine, *Timber Frame Houses*, Taunton Press, Newtown, Ct., 1992. Collection of articles on a wide variety of timber frame designs and techniques.

Timber Framers Guild, *Timber Frame Joinery and Design Workbook*, Timber Framers Guild, Becket, Mass., 1996. Collection of articles on joinery, design and engineering.

Richard Harris, *Discovering Timber Frame Buildings*, Shire Publications, Aylesbury, Bucks, UK, 1978. Great little book from Britain defining terminology and traditional frame typologies.

Les Walker and Jeff Milstein, *Designing Houses*, Overlook Press, Woodstock, N.Y., 1979. Good introduction to the process of going from bubble diagrams to working drawings.

Scott T. Ballard, *How to Be Your Own Architect*, Betterway Publications, White Hall, Va., 1987. Good introduction to developing the design program and drafting techniques.

Winter Panel Corp., "Installation Guide for Timber Framers," free from Winter Panel, 74 Glen Orne Dr., Brattleboro, VT 05301, 802-254-3435, or downloadable from www.winterpanel.com.